

THIRTY-FIFTH ANNUAL REPORT

OF THE

NORTH CAROLINA

Agricultural Experiment Station

OF THE

College of Agriculture and Mechanic Arts

FOR THE

YEAR ENDING JUNE 30, 1912

INCLUDING

Scientific and Other Papers and Bulletins

217, 218, 219, 220, 221, 222, 223

WEST RALEIGH, NORTH CAROLINA

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N. C. COLLEGE OF AGRICULTURE AND MECHANIC ARTS

THE NORTH CAROLINA

AGRICULTURAL EXPERIMENT STATION

UNDER THE CONTROL OF THE

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The Bulletins and Reports of this Station will be mailed free to any resident of the State upon request.

Visitors are at all times cordially invited to inspect the work of the Station, the office of which is in the new Agricultural Building of the College.

Address all communications to

N. C. AGRICULTURAL EXPERIMENT STATION,

WEST RALEIGH, N. C.

NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION,
OFFICE OF THE DIRECTOR,

WEST RALEIGH, N. C., June 30, 1912.

To His Excellency, WILLIAM W. KITCHIN,
Governor of North Carolina.

SIR:—I have the honor to submit herewith the report of the operations of the North Carolina Agricultural Experiment Station of the North Carolina College of Agriculture and Mechanic Arts for the year ending June 30, 1912.

Trusting that this report will prove satisfactory to your Excellency,
I am, Yours very truly,

C. B. WILLIAMS,
Director.

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THIRTY-FIFTH ANNUAL REPORT
of the Director of the
N. C. AGRICULTURAL EXPERIMENT STATION
for the Year Ending June 30, 1912

BY THE DIRECTOR.

During the year the work of the Station has progressed mainly along the lines mentioned in previous reports. Some new lines of investigation have been started and some old ones completed. The nature of the investigations may be gathered from the brief resumé of the work of the different Divisions given below. This is made up from the reports of the heads of Divisions and from the personal observations of the Director.

DIVISION OF AGRONOMY.

The work of this Division has advanced during the year along the same general lines as previously reported; chief attention having been devoted to the corn suckers and soil fertility investigations. In the former investigation an effort is being made to determine the cause of the development of suckers on the corn plant and the relation their production, and prolificacy in ears, sustain to total yield of shelled corn per stalk under different degrees of soil fertility in different seasons. It will also furnish a means by which the correlation between types of corn and different degrees of fertility of the soil will be made and at the same time furnish material for a detailed study of the characters of the corn plant.

For this investigation eight varieties, representing the three common types, viz., one-eared, medium prolific, and very prolific, of dent corn have been chosen. The eight are each planted under seven different conditions of soil fertility, varying approximately from land that will produce ten to eighty or one hundred bushels per acre. The differences are brought about in the land by the use of different quantities of stable manure and commercial fertilizer. In each set there are thirty-two rows, four to each variety, two from which the suckers are removed and two on which they are allowed to grow. By this means a comparison will be obtained that will show the effects of the undisturbed production of suckers upon yield and other characters of the corn plant under different degrees of fertility of the soil. The gradation in the fertility of the soil in the different sets will provide an opportunity for a comparison of the relative productivity of the three general types of dent corn, as represented by the eight varieties included in the studies, when grown under the different degrees of fertility. It has been found generally that the yield of grain and stover per stalk, and hence per acre, has been greater with all varieties where the suckers were allowed to remain than where they were removed at the usual stage of development.

With the same variety, it was found that stalks bearing suckers were somewhat lower than those from which they were removed. A decidedly larger percentage of smutted stalks were found on the more fertile plats, and on the portion of plats with the different varieties on which suckers were allowed to grow. In the test last year Biggs' Seven-ear, the most prolific variety ever tested at the Station, yielded the highest amount of shelled corn per acre, with Cocke's Prolific, Sanders' Improved, Weekley's Improved, Brake's, Hickory King, Wyatt's Improved Yellow and Holt's Strawberry ranking in the order given.

The soil fertility investigations have been continued with cotton and corn along the same general lines as reported in the previous year. During the excessively dry weather of the past summer, cotton responded well to the heavier applications of commercial fertilizers, while corn did not seem to be but little influenced in yield by such applications. Much better results were shown with cotton from the use of lime than with corn. Bacteriological and Chemical studies are being made on some of the plats. The samples are being drawn monthly for these examinations. Results thus far have shown marked differences in the bacterial count of plats of different degrees of productivity. The study of different phosphatic and nitrogenous carriers of plant food with cotton and corn have been continued, particular attention during the year being devoted to acid phosphate, basic slag, finely ground phosphate rock, Peruvian guano, potash manure, solubilized organic nitrogen, beet refuse compound, calcium cyanamid, dried blood, nitrate of soda, sulphate of ammonia and Kanona tankage.

In the study of varieties of different crops, thirty-eight of cotton; eight of corn; seventeen of wheat; twenty-one of oats; twenty-four of cowpeas; seventeen of soy beans; and seven of adsuki beans are being used this year.

Some of the leading varieties for the conditions as represented by the Station farm as shown by the averages of three or more years' trials are: for cotton, Culpepper's Re-improved, Broadwell's Doublejointed, Toole's Prolific, Moss' Improved, King's Improved and Simpkins' Prolific; for corn, Sanders' Improved, Cocke's Prolific and Weekley's Improved; for wheat, Red May, Purple Straw, Leap's Prolific, Currell's Prolific, Golden Chaff, Fultz and Harvest King; for fall sown oats, Virginia Gray, Appler, Bancroft, Red Rust Proof and Burt; and for cowpeas in yield of shelled peas, New Era, Whippirwill, Small Blackeye, Groit, Iron, Blackeye and Black.

Special selection and breeding work is being carried on by this Division with cotton and wheat in an endeavor to secure strains of these crops better suited to our conditions and at the same time that will prove more highly productive than the varieties of these crops now commonly grown. One selection of cotton and two of wheat have been secured which are very promising as shown by this year's results. In the spring of 1911 work was started with cotton in an effort to determine the type of cotton best suited for growing under different degrees of fertility of the soil in the same locality. Also, in this experiment, the different characteristics of the varieties are being studied when grown

under different degrees of fertility of the soil, as complete notes are being made throughout the growing and harvesting season by trained observers. It is planned to extent this work to other crops and localities. At present Culpepper's Improved, Russell's Big Boll and King's Improved varieties are being used. Thus far the results indicate that for the most highly fertilized and manured soil Russell's Big Boll is the best yielder of the three, if the season is sufficiently long to mature this variety.

In the study that is being made of the value of kernels of corn taken from different portions of the ear for seed purposes, the results have thus far shown that those from the middle of the ears produced stalks that yielded the heaviest, while those from the tips and butts were the smallest yielders.

Different systems of rotation for cotton and corn farmers are being worked out on the Station farm.

DIVISION OF CHEMISTRY.

Most of the time of the workers of this Division has been taken up during the year with work in connection with the soil bacteriology and cottonseed meal investigations which this Division is conducting in co-operation with other Divisions of the Station. Chief attention has, however, been given to the furtherance of the cottonseed meal toxicity work. Rabbits have practically replaced guinea pigs in these investigations in all the detailed work, as the former have been found decidedly most satisfactory. Most of the important results secured with rabbits are checked up with swine. The feeding has been both by natural and forced methods. Many chemical solvents, ferments and digestive fluids such as hydrochloric acid, sulphuric acid, sodium hydroxide, sodium chloride, ammonium citrate, acetic acid, water, ether, chloroform, alcohol, alcohol and acetic acid, alcohol and sodium chloride, yeast, pepsin, pancreatin, and a mixture of pepsin and pancreatin have been employed in the studies on upland and Sea Island cotton seed and meal. The work thus far has shown that whatever the solvent used the extracts have been found to be nontoxic, and the residue toxic, except in the case of forced feeding with rabbits, where an equivalent of eight or ten times the normal feed of meal was administered.

In feeding Sea Island cottonseed and meal to swine in varying daily quantities from 0.7 to 2.2 per cent, their body weight, it killed in every case but one. The results indicate that the seed and meal from Sea Island is just as toxic as that from upland cotton. The meal was found to be much more toxic to young than to older hogs.

Results secured during this and the previous year with rabbits, guinea pigs and hogs have led the investigators to conclude that the toxic principle of cottonseed meal was not a salt of pyrophosphoric acid as claimed by Crawford.

It has not been found possible to transfer the toxic substance, if such it be, from an animal suffering from cottonseed meal poisoning to a healthy animal. Results secured indicate that cottonseed meal is quite toxic to young calves when they are fed on it.

The first positive results have been secured in the cottonseed meal toxicity investigations during the present year. In previous years all the results were of a negative character. It has been found that an alcoholic solution of caustic soda greatly reduces, if not entirely overcomes the toxicity of cottonseed meal. The more recent results and observations seem to indicate quite strongly that the toxicity of the meal is due to its acid properties.

In the soil bacteriological investigations which this Division has been conducting jointly with the Division of Plant Pathology and Bacteriology, the work during the year has been confined largely along three lines: (1) to determining the ammonifying and the nitrifying efficiency and nitrification inoculating power of soils from two plats in the Soil Fertility series of widely varying productiveness; (2) to a study of the effects of varying substances upon denitrification in the soil and in solution; and (3) to an attempt at isolation and study of the organism concerned in denitrification.

During the year several papers have been prepared by the workers of this Division embodying results secured in the cottonseed meal toxicity and soil bacteriology investigations, and presented at the meeting of a number of scientific societies.

The sugar beet coöperative experiments which this Division is conducting jointly with the Bureau of Plant Industry with farmers of the State are progressing satisfactorily. The results secured during the fall from the beets grown in many of the mountain counties, indicate strongly promise for the counties of Ashe, Henderson, Jackson, and Watauga, as beets grown in these were of good size and contained more than 14 per cent of sugar. This work has been enlarged and is being continued. The work of this Division has been greatly facilitated by removal during the early part of the fiscal year to larger and better equipped quarters on the third floor of Winston Hall.

DIVISION OF ANIMAL HUSBANDRY.

During the year much of the efforts of this Division has been taken up with work involved in the cottonseed meal toxicity investigations which are being conducted jointly by this, the Chemical and the Veterinary Divisions. The policy of previous years of carrying on most of the detailed experiments with rabbits has been continued, but considerable work has had to be done with swine. Following the publication of the observations and results of Crawford with reference to a salt of pyrophosphoric acid being the cause for the toxicity of certain kinds of cottonseed meal, the workers of this, the Chemical and the Veterinary Divisions, planned and started experiments to check up these results. Contrary to the findings of Crawford, it has been found that Sea Island cotton seed and meal are as toxic as is the seed and meal from upland cotton. Sodium pyrophosphate fed to two pigs for 198 days in daily quantities, equivalent to the total amount of phosphoric acid contained in two pounds of cottonseed meal, failed to kill or even to lead to the development of unfavorable symptoms. One of the most striking features of the Sea Island cottonseed meal feeding was the death of the

hogs without premonitory symptoms, after being fed for 208 days and then being run for a few moments in an effort to get them on the scales to be weighed.

From the results of the feeding experiments with horses and mules concluded last summer, it is suggested that one of the most practical cottonseed meal rations for farm work stock, weighing on an average of about 1,000 pounds, would be a feed made up of 10 pounds of corn-and-cob meal and 2 pounds of cottonseed meal per day. If the amount of cottonseed meal exceeds 2 pounds per day the animals will likely refuse it after about three months feeding. The beef cattle feeding experiments which were mentioned in the report a year ago were repeated during the past winter. From the results of work of three years it is clear that the feeding of a good grade of steers during the winter months in North Carolina may be made to return some profit to the intelligent feeder. The results this year have demonstrated the superior value of corn silage over cottonseed hulls as a roughage when fed with cottonseed meal. With corn silage as the roughage, profitable gains may be made for a much longer period than with either cottonseed hulls or corn stover. After 80 to 90 days the lot of steers fed cottonseed hulls began to show diminished gains, while those fed corn silage continued in good condition and made substantial daily gains for 165 days. One lot of steers receiving corn silage as the roughage were fed 2.3 pounds of cottonseed meal per day for a 40-day preliminary period, and after that in regular experiment received a daily feed of 9 pounds of meal for 120 days. In the 165 days this lot of steers consumed 1,237 pounds of meal per steer. The results of this year seem to establish the fact that where dry roughages like cottonseed hulls and corn stover are used in connection with cottonseed meal for fattening cattle the period of profitable feeding is much shorter than when a succulent feed like corn silage is used with the meal. The grazing experiments with swine, previously mentioned, are being continued along the same general lines as reported. Such crops as cowpeas, soy beans, rape, Canada field peas and oats are being used. A flock of twenty grade ewes have been added to the equipment of the Division for experimental purposes. During the year the Division has published three bulletins on the feeding and management of beef cattle and one on the feeding, care and management of sheep. The facilities for the workers of this Division have been materially improved during the year by the addition of stock and equipment.

DIVISION OF HORTICULTURE.

During the year the main energies of the workers in this Division have been devoted to work in connection with the investigations that are being conducted on the self-sterility of blackberries, dewberries, and muscadine grapes, and on the transmission of characters in hybrids of the latter. The work on self-sterility of muscadine grapes has been practically completed and the results were published in bulletin 209; that on dewberries and blackberries will probably be finished at the end of the present growing season. Of the twenty-three varieties of blackberries under observation McDonald, Rathbun, Sorshy, May and Spaulding have

been found to be self-sterile, the others have been found capable of complete self-fertilization. With dewberries, those varieties of the Southern type (*Rubus trivialis*) have generally shown to be self-sterile, while those of the Northern type (*Rubus villosus*) are self-sterile. This year some flowers of three varieties of dewberries and of all the twenty-three varieties of blackberries have been hand pollinated and bagged in continuation of the investigations. The studies of the pollen of self-sterile varieties have been continued and have shown it to be viable in every case, hence self-sterility can not be attributed to impotency of the pollen. As the results with muscadine grapes have shown that all the cultivated varieties studied are unable to bear fruit, unless pollen from a male vine is supplied, they emphasize the importance of having in or near muscadine vineyards male muscadine vines. The pollen of the bearing vine does not seem to be active.

The investigations that have been conducted for some years by this Division as to the nature and cause of double-flower of blackberries and dewberries have been completed and the results published. It was found (1) that the trouble was due to a fungus; (2) that a method of pruning in which all the wood showing above the ground is removed after fruiting is quite effective in keeping the disease in check; and (3) that this treatment followed by a spraying with Bordeaux mixture will practically insure the grower against the ravages of the disease. In the study of the transmission of characters in hybrids of muscadine grapes, several varieties are being used. An effort is being made to determine if such characters as color of berry, persistence of holding fruit and size of fruit clusters are transmittible, and if so what are the laws governing transmission. From the first and second lots of crosses of different varieties, there are now growing in the field and in the greenhouse 3785 seedlings. Numerous new crosses were again made during the past spring. It will be necessary to continue the studies on the resulting hybrids for several years so that their blooming and fruiting habits may be determined. An investigation of the variations of the scuppernong grape propagated asexually is being made.

Some work is being conducted on the self-sterility, self-fertility and the cause of seedlessness in the persimmon, but this work has not advanced sufficiently to make any deductions at this time. The experiments previously mentioned, designed to study the effects of different methods of pruning apple trees have been continued during the year.

DIVISION OF VETERINARY SCIENCE.

During the year the Veterinarian has devoted his energies chiefly to work in connection with the cottonseed meal toxicity investigations which this Division is conducting jointly with the Chemical and Animal Husbandry Divisions. Observations have been made on cattle, swine, rabbits and guinea pigs which were fed cotton seed, cottonseed meal and pyrophosphoric acid. With a calf fed heavily on meal for 275 days before dying, unthrift was noted early in the feeding but he did not develop serious symptoms until about ten days before death. Autopsies on one calf, seven hogs, forty-eight rabbits and fifteen guinea pigs have

revealed the following fairly constant lesions: excess of abdominal and pleural fluids; irritation of the mucus membrane of the stomach and intestines; reddening of the lymph nodes; edema of the lungs; and the formation of ante-mortem clots in the heart. Histological examinations are being made on a number of selected sections of affected tissues by a prominent comparative pathologist of the Kansas City Veterinary College. Numerous examinations of domestic animals infested with various verminous parasites have been made by the Veterinarian and remedies recommended. This class of parasites has been found to be quite common in the State among horses, sheep, cattle, swine and dogs. In a single pig long worms, common round worms, thorn headed worms, whip worms, nodular worms, kidney worms, tape worms and muscular trichinosis were found. Some attention has been given by the Division to the improvement of the meat and milk inspection of some of the larger cities of the State. The Veterinarian has recommended that a competent inspector be provided to make ante- and post-mortem examinations, market inspection of meats, and inspection of dairies and milk supplies. Information with reference to meat and milk inspection service has been supplied the authorities of a number of cities of the State. The Veterinarian has prepared a bulletin during the year on "Infectious and Parasite Diseases of Domestic Animals," particularly with reference to those prevalent in North Carolina.

DIVISION OF PLANT PATHOLOGY AND BACTERIOLOGY.

The main work of this Division has been directed along the same general lines as previously reported. In the tobacco wilt investigations which are now being conducted at Creedmoor and at West Raleigh, a further study has been made of the value of different soil disinfectants in overcoming or in reducing this trouble. The effects of soil type, soil acidity and subsoiling with dynamite upon the development of the wilt are being carefully noted from cylinder and field experiments. From rotation trials, it is hoped to determine the longevity of the parasite in the soil causing the disease and at the same time work out a more rational system of rotation for the tobacco farmers of the infected area. Promising strains from crosses of different types of tobacco grown in previous years are being grown and studied. New and promising varieties are included in the work from time to time.

The watermelon wilt experiments that have been previously conducted by the Station in cooperation with the Bureau of Plant Industry at Auburn on wilt infected soil are being continued independently by this Division. Forty-one different selections, twenty-six from Auburn and fifteen from Monetta strains, are embraced in the studies this year. The plants showed a resistance of more than 95 per cent from the planting of last spring. The melons proved to be of good size and of excellent eating qualities, but were found to possess quite a brittle rind which rendered them unsuitable for shipping purposes.

Laboratory studies have been conducted during the year on the two most destructive fungous diseases (*sclerotinia libertiana* and *botrytis vulgaris*) of lettuce occurring in the State. In many sections the former

of these diseases has caused a loss of fully 70 per cent of the plants. This disease may be recognized from the fact that the leaves suddenly wilt much as though they had been scalded with hot water. In a day or two the whole plant is dead and the leaves fall flat on the ground. Examination of the under-side of such leaves shows them to be covered with a fine, white cotton-like growth. A few days later irregular black bodies, varying in size from a mustard seed to a grain of corn, are found. These three signs enable one to easily recognize the disease. Heretofore this disease has been considered practically incurable, but recent work of this Station seems to indicate that it can be controlled if proper measures are observed, to such an extent as to reduce the loss to a very small percentage of the crop, if not entirely eradicate the disease.

During the past year in the Soil Bacteriological investigations which this Division is conducting jointly with the Chemical Division, denitrification has been studied chiefly, particularly with reference to the bacteria concerned in the phenomenon and the conditions which hinder or facilitate the process. In this work small uniform plats are used for testing the effects of nitrate of soda, sulphate of ammonia and cottonseed meal upon the bacterial processes of the soil. Oats, wheat and millet have been used as the crops. Chemical and bacteriological determinations are being run on the plats at certain intervals during the growing season. The monthly study of the nitrifying and ammonifying activities of the low and high yielding plats in the Soil Fertility plats of the Agronomy Division is being continued with marked differences. The investigations by this Station during the past few years have developed the fact that the nitrifying power of North Carolina soils is much lower than the nitrifying power of soils is usually considered to be. Some attention has also been given during the year to a study of the relative value for fertilizing purposes of ammoniacal and nitrate nitrogen.

In the Apple Disease investigations, European canker, wart or twig tumors and orange rust or cedar rust have engaged most attention. During the spring of 1912 spraying experiments with Irish potatoes were started in one or two different localities in the State to determine the comparative value of various fungicides on the growth and yield of the crops, the best time to make applications, the cost for such treatments and the net returns per acre. It is planned to continue these experiments for four or five years.

Three bulletins have been prepared by the Division during the year, two on "A Serious Lettuce Disease" and one on "A Serious Cotton Disease and How to Handle It."

DIVISION OF ENTOMOLOGY.

The time of the Entomologist has been devoted chiefly to work in connection with corn bill bug investigations. His efforts have been confined largely to a study of one species (*S. Callosus*), as it is thought that practically all the damage to corn in the State is caused by this one. From the life-history studies carried on in an outdoor wire cage, it is practically certain that one full generation occurs each year and a partial

second one may occur, but the records secured indicate that the latter occurs only rarely. From seasonal life history studies it has been learned (1) that the adult beetles pass the winter in corn stalks and elsewhere; (2) that they emerge in the spring and feed on corn, rice or cyperus grass; (3) that they commence laying eggs during the latter part of May; (4) that the eggs, larvæ and pupæ occur all the summer and fall; and (5) that adults are emerging all the year after the first of July. In the outdoor cage the beetles have been found to hibernate mostly in the first inch of soil. The investigations have shown that it required on an average of 6 days for incubation of the eggs, 33 days for the larval stage, and nine days to pupate. Plans have been made for continuing this work this summer in badly infected fields at the Pender Test Farm under field conditions. The results of the studies on two species (*S. callosus* and *S. parvulus*) have been embodied in two articles for publication in this Report. These include records on all phases of the beetles; feeding habits and development of the larvæ; formation of pupæ cells and duration of pupal stage; emergence of adult beetles, and habits of adults after maturity. From the results of the investigations that have been carried on, it does not appear that the little grass bill bug (*S. parvulus*) occurs in this State in sufficiently large numbers at present to be considered a serious pest. Although no direct experiments have been conducted to control the corn bill bug, it is the belief of the Entomologist from observations that winter plowing and a rotation of crops will undoubtedly prove effective against this pest under North Carolina conditions. Considerable work during the latter part of the year has been conducted on the life history of the Gloomy Scale. This insect is a most important enemy to the shade trees of North Carolina, having been reported from all the cities and larger towns of the Piedmont and Coastal Plain sections. It is especially injurious to soft maples, which have been so largely used for shade purposes along our city streets. For this work all the small trees on the College campus are available. The biological studies on two species of melon worms which have been carried on by this Division for the past two years were completed during the early part of the year. The results as secured have been put in shape and published in bulletins and reports of the Station. The web-worm investigations started about three years ago have been suspended temporarily owing to lack of material with which to work.

Some attention has been devoted to a study of cotton leaf worm, corn stalk borer and corn weevils, all of which have been quite numerous in the State during the past year. Particularly so with the corn stalk borer, as in many fields examined more than 60 per cent of the corn stalks were infested with this pest.

DIVISION OF POULTRY HUSBANDRY.

With this Division the efforts of workers have been confined chiefly to work in connection with feeding experiments. During the early part of the year different lots of hens were fed experimentally in two series, one

of which was confined in medium sized yards and the other which was allowed range on large lots, in which farm crops were kept growing, as much of the time as possible. The four rations tested under these two conditions were, (1) corn alone; (2) wheat alone; (3) a mixture of two parts of corn and one part of wheat with a dry mash made up of equal parts of corn meal, wheat bran and cottonseed meal; and (4) same as latter, except that a mixture of equal parts of wheat and bone meal was substituted for cottonseed meal. These rations were tested for profitable egg production and for their effects upon the breeding qualities of the fowls. In all cases the fowls in the larger yards which were provided at all times with an abundance of green feed gave better results than did those on the same rations in the small yards during the six months of the experiment. With rations Nos. 1, 2 and 3, the cost of production of eggs was so high that the fowls in the small yards were fed at a loss and those in the larger lots at a very small profit. With ration No. 4 there was a marked reduction in cost over the other lots, and here a fair profit was secured.

The production of eggs was from 20 to 33 per cent less in the larger lots than in the small ones. There can hardly be any doubt that the very dry weather that prevailed during the course of the experiment was not favorable for best results with any of the rations. With some modification the experiments in feeding were continued during the past spring. The hens in pens fed a mixture of four parts of corn meal, four parts of wheat bran and two parts of bone meal have laid the largest number of eggs and have done it at the least cost per dozen for feed. Both of the lots were on green crops, one on Bermuda grass and the other on growing oats. The eggs cost for feed from hens in these 10.8 and 10.6 cents per dozen respectively. It is proposed to continue the experiment through next fall and winter, so that the period of least supply of eggs and high prices may be covered. The pens will be made up of units equally divided between yearlings and pullets. Bulletin on "Profitable Poultry Raising" has been prepared by the Poultryman during the year and issued.

There has been an increased demand upon the time of the head of this Division in the way of correspondence and in demand for lecture work in connection with farmers' institutes, poultry shows, short courses, girls' poultry clubs and other meetings of a public nature.

ADAMS PROJECTS.

The following is a list of Adams projects on which work is being carried on at the present time:

Investigations of lettuce and apple diseases.

Soil nitrification with reference to the bacterium concerned and its isolation.

Relation of geology and chemistry of soils to productivity and fertilizer requirements.

Investigation of the cause of the development of suckers on corn and the relation of their production, and prolificacy in ears, sustain to total yield per stalk under different conditions of soil and season.

Investigations on double-flower of blackberries and dewberries and sterility of blackberries, dewberries and muscadine grapes.

Investigations into the nature of the cause for cottonseed meal feeding resulting disastrously frequently when fed to swine.

Field and laboratory studies of yellow sides.

Biological studies of injurious species of corn bill bug occurring in North Carolina.

Study of the transmission of characters in hybrids of rotundifolia grapes.

A life history study of the Gloomy Scale, *Chrysomphalus thebricosus*, Comstock, together with an inquiry into the effectiveness of certain remedies.

BUILDING AND EQUIPMENT.

During the past summer the Chemical Division moved from the first floor of Holladay Hall to the second floor of Winston Hall. By thus doing an increase of almost three times the floor space was secured. Considerable new equipment has been added in the Agronomy and Animal Husbandry Divisions during the year. Because of insufficient water supply at the farm for the stock practically all of last year after the opening of spring a six-inch drilled well was put in. The well is 132 feet deep, 94 feet of which is through rock and has a flow of about 8 to 10 gallons of water per minute. The windmill originally at the Poultry plant has been installed at the farm to supply water to the stock from an open well in case of emergency. The water system has been extended to the superintendent's house, the barn and all the feeding and grazing lots. The contract for a five-roomed cottage for the superintendent of the farm has been let and work is well under way. It is expected that the cottage will be ready for occupancy by July 15 to August 1. Two buildings, one 10x20 feet and one 10x10 feet, have been built at the Poultry yards. A concrete silo, a concrete hog house and considerable other work of this nature has been done at the farm since the beginning of the year.

BULLETINS.

Bulletins have been prepared and have been issued during the year as follows:

- No. 217—A Serious Lettuce Disease, by F. L. Stevens.
- No. 218—Feeding Experiments with Beef Cattle, by R. S. Curtis.
- No. 219—Feeding and Management of Beef Cattle, by R. S. Curtis.
- No. 220—Care and Management of the Dairy Herd, by J. C. McNutt.
- No. 221—Profitable Poultry Raising, by J. S. Jeffrey.
- No. 222—Cottonseed Meal and Corn Silage Feeding Experiments with Beef Cattle, by R. S. Curtis.
- No. 223—Sheep Raising, by R. S. Curtis.
- No. 8 (Technical)—A Serious Lettuce Disease and a Method of Control, by Stevens and Hall.
- No. 23 (Press)—A Serious Cotton Disease (Anthracnose) and How to Handle It, by F. L. Stevens.

DIVISION OF AGRONOMY.

Below is given a report of the field experiments of the Division of Agronomy for the year ending June 30, 1912:

Corn Suckers Investigations.—This test occupied the same land as last year, but instead of having 59 varieties the number was reduced to eight, each variety being selected with the view of representing a particular type of corn. The test is designed to determine the correlation of the different types with varying conditions of fertility of the soil. The land devoted to the test is divided into seven equal parts with a blank space between each of the sets. In each set there are 32 rows, four of which are planted to each of the seven varieties, this giving 1-20 acre to each variety in each of the seven sets, or a total of 7-20 to the variety. The sets have been treated in such a way as to bring about differences in soil fertility, gradating from set one as the most fertile to set seven as the poorest. The first three sets received heavy applications of stable manure in 1909 and 1910, also heavier application of commercial fertilizer than the others. It was planned to have the soil of the plats range in yielding capacity from 75 to 100 bushels from plat No. 1 down to 8 or 10 bushels per acre for plat No. 7. With a view to determining the effect of removing suckers from the stalks, the first two rows of each variety in all of the seven sets had the suckers removed, giving for each variety in each set 1-40 acre with suckers removed, and an equal acreage with suckers unremoved. Each variety is planted under fourteen different conditions, seven differences in the fertility of the soil, and in each case the variety is grown with and without suckers. The number of suckers which varieties of corn produce seem to be determined principally by the following factors: (1) by the addition of available plant-food to the soil which stimulates the plants to increased growth; (2) by better cultivation, which increases the feeding area of the roots, setting free plant-food and conserving moisture, etc.; (3) by late planting, which causes an abnormally rapid growth; and (4) by the amount of rainfall, suckers being more numerous, other things being equal, in wet than in dry seasons, especially if the rain comes when the corn is from two to four weeks old.

In every set except the first, the yield of shelled corn per acre was greater for the half-plats on which the suckers were left, but on the first set there was scarcely any difference in yield of shelled corn between the half-plot on which the suckers were left and the one from which they were removed. The average weight of stover per acre was much greater with the different varieties of the highly fertilized plats for the half-plats from which the suckers were removed, being almost double the yield in some cases. The ears from the half-plot on which the suckers were left were more in number than were those from the other half-plot, but averaged smaller both in length and diameter. There was quite a marked difference in height of the stalks, with and without suckers, those without suckers being the taller. There was no marked difference in the height of the ears on the stalks of those half-plats from which the suckers were removed and on which they were left. In both cases the

number of smutted stalks per plat was directly proportional to the fertility of the soil, the number being higher on the heavily fertilized and manured plats. The average number, however, being much greater on the half-plat on which the suckers were left.

In the variety test with the seven sets, Biggs' seven-ear averaged first in rank in amount of shelled corn per acre, having first place in four sets; Cocke's Prolific ranked second with one first place. The other varieties ranked as follows: Sanders' Improved, third; Brake's and Weekley's Improved tied for fourth place; Hickory King, fifth; Wyatt's Yellow Improved, sixth; and Holt's Strawberry coming last.

In comparison with other varieties, Hickory King proved a better comparative yielder as the soil grew poorer, while Holt's Strawberry showed to be the reverse.

The corn variety and sucker tests were continued in 1912 without change from 1911, except that none of the plats received manure.

Cotton.—As in previous years some difficulty was encountered in securing a new supply of seed of all the varieties for planting, in fact with some of the varieties it was not possible to secure seed. In place of these, new ones were substituted. Thirty-eight varieties were tested out this year. In all 14 new varieties are being tested this year, six of which are field selections from varieties already grown. These were No. 3A for Columbia Long Staple; No. 4 from Toole's Prolific; No. 9A from Smith's Double-header; No. 5A from Cleveland Big Boll; and No. 14 and No. 17 from Culpepper's Improved. With 38 varieties tested, 5A ranked second in the amount of seed cotton produced per acre, Haynie's Queen of Georgia being the leading variety. Six out of the 14 new varieties produced above the average in yield. Cleveland Big Boll is the only variety that has shown any marked evidence of having been improved by selection.

This test will be continued. Some of the old varieties will be discontinued and others will be substituted in their places.

Wheat.—The variety test of wheat has been carried on now through five years (1906-1911) with from ten to seventeen varieties in each test. Last year the test included fourteen varieties which had been previously used, together with three new strains (1A, 2A and 4A), which were grown from selected seed from the plant breeding plats. The seven varieties which ranked highest in yield last year were 1A, Purple Straw; 2A, Currell's Prolific, Red May, Red Wonder and Fultz's Mediterranean in the order given. Purple Straw still holds on as averaging the highest in rank of production of grain per acre. The test will be continued possibly with three or four additions.

Oats.—The work last year with oats was simply a continuation of the oat variety test started in 1907. Red Rust Proof, Appler, Burt, Bancroft and Virginia Gray were first in the order given, producing 32.2, 32, 31.3, 30 and 28.7 bushels per acre, respectively. The next variety in yield fell quite a bit below those mentioned above. The varieties in the order given above matured in 214, 215, 205, 215 and 222 days from the date of planting. Dry weather cut down the yield of the varieties materially, especially the late maturing ones.

In the 1911-1912 test many of the varieties had a poor stand due to the hard winter, the freezes killing out a large per cent of the less hardy varieties.

Cowpeas and Soy Beans.—Variety tests of cowpeas and soy beans have been carried on since 1903 with more or less thoroughness each year. Only in 1909 and 1910 was the work full enough for the results to be of the greatest value. Last year the season was so dry and it was so late before the test could be put in that the test for seed production could not be made. There were 24 varieties of cowpeas, 17 varieties of soy beans and 7 varieties of adsuki beans planted.

Owing to late planting, many of the varieties of cowpeas failed to put on enough fruit to note, so it was decided to cut the entire test for hay. This was done October 21, at which date the following varieties had passed the best hay stage: Red Ripper, Holstein, Small Blackeye, Black, Powell's Early Prolific, Large Blackeye, Brown Coffee, Early Unknown, and Whittle. They had shed a portion of the leaves which, of course, made them weigh somewhat lighter than they would had they been cut a little sooner. The eleven highest producing varieties were as follows: Iron, Groit, Brabham, India, Southdown, Small Black, Whippoorwill, Ayrshire, Clay, Unknown. The India variety was so late in maturing that it did not put on fruit. It held its leaves well and stayed green longer than any other variety. Owing to this characteristic combined with its small stems it is considered as well or better suited for hay than any of the other varieties and is but slightly below the most prolific yield.

The adsuki beans did not make very much growth last year on account of the very dry season. All the varieties matured seed.

FERTILIZER EXPERIMENTS.

Main Plots—The main corn and cotton plots in the soil fertility investigations were continued during the past year, the usual fertilizer application again being supplemented with an application of stable manure at the rate of 7.6 tons per acre. The application of manure which was made December 14-20, 1910, was applied with a manure spreader, special pains being taken to distribute the manure evenly over the entire area.

In general the results gotten last year from this test were in line with the results of the previous year, being slightly more emphasized by the second application of stable manure. The cotton plots responded again to heavy applications of commercial fertilizer, while the corn plots seemed not to be affected materially by these applications. The corn did not show any marked response to an application of lime, either with or without commercial fertilizer. The cotton, however, showed some effect of lime when used alone and a more marked effect when used with fertilizing materials. The most marked feature in the whole test is the remarkably high yield of cotton on the plot receiving Thomas slag and stable manure. This high yield has run for some years with the cotton and is gradually increasing each succeeding year.

The soil fertility investigations will be carried on in the usual manner this year, there being no application of stable manure.

Culture Tests.—Rotation, distance and culture tests are being continued along the same lines as previously mentioned. The distance tests particularly gave very promising results last year.

Phosphate Slag.—The phosphate slag test with cotton was continued on the same land as used last year.

With corn in the phosphate slag test applications of materials carrying potash, nitrogen and phosphoric acid resulted in increased yields, carriers of phosphoric acid giving the best results.

Phosphate Rock.—The tests with finely ground phosphate rock on corn and cotton were continued during the year. With corn the largest yield was obtained from the plat receiving the most nitrogen and phosphate, but the increase in yield did not pay for the cost of the extra application. Potash showed an increase in yield only up to the normal application. The cotton plats, receiving an application of stable manure and of ground phosphate rock, gave a higher yield than did the plats receiving dried blood and phosphate rock. The plat receiving 4,000 pounds of manure and 160 pounds of phosphate rock per acre produced 255 pounds more of seed cotton per acre than did the plat receiving 149 pounds blood and 204 pounds phosphate rock.

Miscellaneous Fertilizer Tests With Corn and Cotton.—This test embraces a field study of the fertilizing value of various new nitrogenous fertilizing materials that have come on the market in recent years. The test includes a study of tankage, of potash manure, of solubilized organic nitrogen, of beet refuse compound and of calcium cyanamid. These were tested in comparison with the better known nitrogenous materials such as dried blood, sulphate of ammonia and nitrate of soda as carriers of nitrogen for plant growth. In the corn test the rank of the materials is shown by the yields of shelled corn per acre as follows in the order given: Calcium cyanamid, nitrate of soda, sulphate of ammonia, potash manure, dried blood, beet refuse compound, and solubilized organic nitrogen. For cotton the rank of the different carriers were nitrate of soda, sulphate of ammonia, calcium cyanamid, blood, tankage, solubilized organic nitrogen, beet refuse compound, and potash manure, in the order mentioned.

Peruvian Guano.—The Peruvian guano test has been continued along the same lines as reported last year. An application of Peruvian guano alone at the rate of 250 pounds per acre gave an increase of 490 pounds of seed cotton per acre over the plat receiving no application of fertilizer; while the plat receiving 500 pounds of Peruvian guano per acre gave an increase of 120 per cent over the plat receiving no fertilizer. The plat to which was added a mixture of 162 pounds of Peruvian guano, 65 pounds nitrate of soda, 35 pounds manure salt and 55 pounds acid phosphate gave the second highest yield, falling below the plat receiving 500 pounds of Peruvian guano only 70 pounds of seed cotton per acre.

Variety-Fertility Tests with Cotton.—This test was begun in 1911 to determine the correlation between soil fertility and types of cotton. It was put on land previously devoted to the variety-distance test of cotton. In this investigation three types of cotton were chosen for the experiment, each type being represented by a well known and distinct variety.

The varieties used were Culpepper's Improved, King's Improved and Russell's Big Boll. Each was planted under three different conditions of soil, the differences being brought about by the addition of different quantities of commercial fertilizer. The land was divided into three sets, giving five rows ($\frac{1}{12}$ acre) to each variety in each of the three sets.

The first set received 200 pounds of cotton fertilizer mixture at time of planting; the second, 400 pounds of the same fertilizer at time of planting, and 100 pounds of same with 50 pounds of nitrate of soda as a side dressing on July 1. The third received 600 pounds of the cotton fertilizer at time of planting, 200 pounds of same on June 15, and 100 pounds of same with 50 pounds of nitrate of soda on July 10. In the first two sets, Culpepper's Improved ranked first with Russell's Big Boll second, while in the third set Russell's Big Boll was first with Culpepper's Improved second. Russell's Big Boll seems to be better suited to a rich soil than to a poor one. The variety-fertility test will be continued with slight modification. Sets 2 and 3 had applications of stable manure at the rate of five tons and ten tons per acre respectively on May 11 last.

Planting Various Parts of the Ear.—This experiment is designed to study the effect of continued seed-selection and planting of seed from the various parts of ears of corn upon the yielding power and other characteristics of the resulting progeny. As yet the experiment has not progressed far enough in order to make definite deductions from the results. Thus far seed taken from the middle of the ear has produced stalks that gave the largest field weight, with seed from all the ear coming second, and from the butts third.

PLANT BREEDING.

Seed Selection with Cotton.—This work was begun in 1908 and has been continued as outlined in the last report. The work of each year has met with some degree of success. In 1909 and 1910 some very fine plants were produced from selections and enough seed were secured from six varieties for planting along with the other varieties in the variety test of 1911 and 1912. Out of these selections the one from Cleveland's Big Boll is the only one that has shown any marked increase in production, it showing an increase of 231 pounds per acre over that of the seed of Cleveland's Big Boll, secured from the originator of the variety. In 1911 other promising strains were secured and planted in the 1912 variety test.

Seed Selection with Wheat.—This work is carried on in the same general manner as that with cotton. From the selections of 1909 and 1910 enough seed were secured from three of the strains improved by seed selection to plant in the variety test in 1911 and 1912. These all produced above the average, two taking first and third places in the variety test in yield of grain per acre. The work is being continued both with wheat and with cotton.

C. B. WILLIAMS,
Agronomist.

DIVISION OF CHEMISTRY.

I have the honor to submit the following report of the Division of Chemistry for the year ending June 30, 1912.

During the year the Division was engaged in the following studies:

Soil bacteriology in coöperation with the Division of Bacteriology; toxicity of cottonseed meal in coöperation with the Animal Husbandry and Veterinary Divisions; inorganic plant constituents in coöperation with the Agronomy Division; methods for leather analysis in coöperation with the referee of the Association of Official Agricultural Chemists; sugar beet culture in coöperation with the Bureau of Plant Industry of the United States Department of Agriculture; methods of analysis; and miscellaneous work.

SOIL BACTERIOLOGY.

In these studies this Division has made 1,379 determinations during the year, which include:

Nitrogen as ammonium by magnesium oxide method.....	283
Nitrogen as nitrates, phenol disulphonic acid method.....	759
Nitrogen as nitrates, Tiemann Schultz method.....	79
Nitrogen as nitrites, Griess method	258
Total.....	1,379

In coöperation with the Bacteriological Division it has published the following:

Studies in Soil Bacteriology No. V in the Centralblatt für Bakt. Band 28. Manuscripts for Studies in Soil Bacteriology No. V and No. VI are submitted herewith for publication.

TOXICITY OF COTTON SEED MEAL.

This Division has prepared 59.9 kilograms of cottonseed meal feeds, representing 26 different kinds of feed for Belgian hares. There were used in preparing the feeds 89.9 kilograms of cottonseed meal. The following determinations were made in connection with this work:

Analysis of 96 samples of urine.....	190
Complete toxicological analysis for non-volatile organic poisons, of liver of calf.....	1
Nitrogen in feed.....	6
Nitrogen in urine.....	4
Sodium in feed.....	10
Potassium in feed.....	10
Albumen	38
Phosphoric acid	18
Viscera of animals distilled.....	27
Tests for formaldehyde	24
Tests for hydrocyanic acid	11
Tests for hydrogen sulphide	3
Tests for nitrogen	3
Tests for sulphur	3
Determination of acidity of meal.....	6
Determination of material soluble in hydrochloric acid.....	2
Determination of water soluble material.....	2
Determination of chlorine	2

INORGANIC PLANT CONSTITUENTS.

For the Division of Agronomy this Division has made 29 ash and 23 phosphoric acid determinations in samples of cotton plant.

ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS.

This Division has made the following determinations for the Referee on tannin:

Soluble solid determinations.....	20
Glucose determinations	10
Sugar determinations	32

SUGAR BEET CULTURE.

In the spring of 1911 in coöperation with the Bureau of Plant Industry of the United States Department of Agriculture, this Division distributed samples of sugar beet seeds to 150 farmers residing in 14 counties in Western North Carolina and a few other counties scattered over the State. Eighty samples of beets were taken for analysis during the fall of 1912. Analyses were made by the Bureau of Chemistry of the United States Department of Agriculture. The county of Graham furnished only one sample of beet and it contained less than 10 per cent of sugar. The counties of Buncombe, Caldwell and Madison furnished beets containing between 11 and 12 per cent of sugar; the counties of Mitchell, Swain and Transylvania between 12 and 13 per cent, the county of Avery between 13 and 14 per cent, and the counties of Ashe, Henderson, Jackson and Watauga, beets containing over 14 per cent of sugar.

During the spring of 1912, 388 packages of sugar beet seeds were distributed in the same manner, and during the fall it is expected that the samples will be analyzed as before. The increasing number of samples distributed shows the interest taken by the residents of the mountainous countries.

During the summer of 1911 this Division was removed from Holladay Hall to Winston Hall, just completed. The removal proved to be a considerable interruption of our work, but our facilities are greatly improved. The conditions are far more satisfactory.

Very respectfully,

W. A. WITHERS,
Chemist Experiment Station.

DIVISION OF ANIMAL HUSBANDRY.

I beg to submit the following report of the Animal Husbandry Division for the fiscal year ending June 30, 1912.

One of the principal lines of work under investigation is the cottonseed meal toxicity project which is being carried on in coöperation with the Chemical and Veterinary Divisions. During the year the animal room has been under the direct charge of the Animal Husbandman. The principal phases of the work pursued have been in conjunction with the Chemical Division. A large number of Belgian hares have been fed on extracts, residues and fractions of cottonseed meal. Large hogs have been used in furthering the work of the project where such was possible. Owing, however, to the necessity of fractional separation of the toxic substance not as much work has been done with large hogs as heretofore. Plans are under way for new phases of work with large hogs to test the findings on the small animals used in the laboratory.

During the year, Bulletin 218 on Feeding Experiments with Beef Cattle has been prepared and issued. The object of the experiment, the results of which are reported in this bulletin, were to determine the difference in the feeding value of corn stover, corn silage and cottonseed hulls when fed with cottonseed meal. The results show quite strikingly the great practical value of using corn silage, either as a whole or part of the roughage ration. The finish and greater value of the steers fed on cottonseed meal and corn silage, either as a whole or part of the ration, attested the value of this feed.

The general feeding and management of beef cattle is discussed in Bulletin 219, which was issued as a companion with Bulletin 218.

Bulletin 222, prepared by the Animal Husbandman during the year, deals with the results obtained in the continuation of the experimental feeding of beef cattle. The results secured show the value of corn silage in the beef steer ration where cottonseed meal forms the sole concentrate.

Bulletin 223 on Sheep Raising has also been prepared and published. Sheep raising is discussed from the standpoint of the practical farmer. Frequent calls for information on this subject made it advisable to publish some practical information in bulletin form for the benefit of those interested in this industry.

An additional flock of grade ewes has been added to the live stock of the Division for the purpose of doing experimental work along this line. The Division is fortunate in having the services of Mr. George Evans, a trained English shepherd, for promoting this phase of live stock work.

Considerable correspondence relating to the breeding, care and management of live stock comes regularly to the office.

Respectfully submitted,

R. S. CURTIS,
Animal Husbandman.

DIVISION OF HORTICULTURE.

I have the honor to submit the following report of the work of the Division of Horticulture for the year ending with June 30, 1912.

Since taking charge of the Division on September 1, 1911, the time devoted by the Horticulturist to Station work has been taken up largely with the routine work of the office, and in making plans and arranging facilities for the continuation of the conduct of the experiments in progress. Provision has been made for the systematic filing of data secured and for its preservation. This has been accomplished by selecting a uniform kind of paper, printed with a suitable heading and ruled in a uniform style but in different forms, by which it may be adapted to all classes of data secured in experimental work. It is intended that existing data be transferred and assembled upon this paper and be placed on file where it may be referred to at any time. It is also intended that all data yet to be secured be preserved in the same form. Work on existing records looking towards this end will be taken up as rapidly as time permits. The Horticulturist has taken advantage of two opportunities to visit distant points in the State in order to become better acquainted with existing conditions. The first of these was in connection with the Strawberry Meeting held under the auspices of the Norfolk Southern Railway at Elizabeth City, February 1, and the second, a visit to the Pender County Farm of the State Department of Agriculture, at Willard, March 15. At the latter point the prime object of interest was the training of the *Rotundifolia* grape.

Mr. L. R. Detjen, Assistant in Horticulture, has the conduct of the investigations directly in charge and has devoted his services entirely to station work. His time had been fully occupied in the greenhouse, in the field, and in the office, in attending to the various plantings connected with his work, and in making observations. The Horticulturist wishes to take advantage of this opportunity to express his appreciation of the work of Mr. Detjen and to commend him for his interest in and fidelity to matters in his care.

I. PRINCIPAL INVESTIGATIONS AND EXPERIMENTS.

The following are the major lines of work which are being conducted at the present time under the provisions of the Adams Act.

A. A study of Self-sterility in Blackberries, Dewberries, and Muscadine Grapes.

This experiment naturally divides itself into two parts as follows:

1. *Muscadine Grapes*.—This part of the experiment was practically closed by the publication in September, 1910, of Bulletin No. 209, on the "Self-sterility of the Scuppernong and Other Muscadine Grapes."

2. *Blackberries and Dewberries*.—It is the purpose of this investigation with these fruits to determine (1) what varieties are self-sterile; (2) the cause of self-sterility; (3) what varieties are the best pollinizers of self-sterile varieties, and (4) whether cross-pollination with self-sterile varieties is better than self-pollination.

The results thus far secured point to the following facts, which were in large part reported last year: (1) that of the 23 varieties of blackberries under observation but four—McDonald, Rathbun, Sorshy May, and Spaulding—are self-sterile; (2) that of the 15 varieties of dewberries, Premo, San Jacinto, Chestnut, Manatee, Rodgers, White, Lime Kiln and Munroe are self-sterile; and Lucretia, Austin, Cox and Ruth are self-fertile; e. g., that practically all varieties derived from *Rubus trivialis* are self-sterile, while those from *Rubus villosus* are self-fertile; and (3) that the pollen of the self-sterile varieties of dewberries is effective in fertilizing the flowers of other self-sterile varieties. The observations as to the blackberries have extended over two seasons, and those as to the dewberries, in all but three cases, over three seasons.

The work in progress at present has reference particularly to the determination of the self-sterility or self-fertility of all varieties. To this end all varieties of blackberries are being bagged and self-pollinated to complete the three-year period of observation necessary to the determination of this point. Three varieties of dewberries are also being hand-fertilized to settle the doubt still existing in each case. The third object of this investigation is being carried out by the making of crosses between self-sterile, and between self-sterile and self-fertile varieties. The other two points in this investigation have as yet been untouched. The cause of self-sterility does not lie in the impotency of the pollen in this case as in that of the Muscadine grapes, and further work will be necessary in order to definitely explain the results found to exist in ordinary conditions.

B. A Study of Transmission of Characters in Hybrids of *Rotundifolia* Grapes.

The purposes of this investigation are as follows: (1) to determine whether the white color of the fruit is a unit character which is transmitted; (2) to ascertain which parent determines the color in the first generation of hybrids; (3) to determine whether the persistent habit of the berries of *Flowers Improved* is a unit character, and whether it is transmitted to crosses of these types; (4) to determine whether the large fruit cluster of the variety *Flowers Improved*, and of certain male plants, are unit characters and whether transmissible to crosses; and (5) to determine what variations have occurred in *Scuppernong* grapes by the use of asexual methods of propagation.

Up to the present time no results of sufficiently definite character to warrant publication have been obtained.

During the year about 1,850 seedlings were planted out in the field and constitute the first lot of hybrids secured from varieties of Muscadine grapes. In September, the second lot of seed secured by crossing will be planted in pots in the green house. Observations upon the individual plants of the first lot will be made during the fall and should furnish some interesting data. Cross-pollination looking toward the production of a third lot of hybrids will be the next work to be taken up.

In order to obtain data as to the blooming and fruiting habits of each lot of these hybrids it will be necessary to carry this work on over a period of at least four years. This means that provision for four areas in which to grow the hybrid plants should be made. At present, the first

lot is located in the Horticultural grounds of the College, and the presence of other crops of value, and the absence of other suitable areas having the proper soil for this work, have made it imperative that either a new location be selected for the succeeding three lots of hybrids, or that the second one be planted at half the distance of the first lot and partly on the same land. In any case a new location will be necessary for the third and fourth lots.

II. INVESTIGATIONS SUPPORTED BY HATCH FUNDS.

The minor lines of investigation included in this group are those which are taken up to determine their fitness to be classed as major lines, and those which have sprung from the major lines, but are of minor importance. The following studies have been included in this group:

A. *A Study of the Influence of Plant Food on Pollen.*—This is a project which grew out of the work on self-sterility of grapes. During this year no work has been done on this project because of the absence of greenhouse facilities. It is hoped that such facilities may be secured before another year has passed.

B. *Self-Sterility of Persimmons* is a project which was taken up last year and is expected to yield valuable results. The purpose of this investigation is to determine the identity of self-sterile and self-fertile varieties; the best pollinizers; and to learn the cause of seedlessness in persimmons. A plot of ground in the southeastern corner of the College horticultural grounds has been temporarily set apart for this work, and to it seedlings and varieties have been transplanted. Other varieties have been transferred to it by being grafted on seedlings already in place.

C. *A Study of the Effect of Different Methods of Pruning Apple Trees* is a project on which work was started in February, 1910. This experiment is being carried on in the College apple orchard. The work on it has been continued during the year, and observations are being made.

Before closing this report the Horticulturist wishes to express his high appreciation of your interest and support.

Respectfully submitted,

J. P. PILLSBURY,
Horticulturist.

DIVISION OF VETERINARY SCIENCE.

I beg to submit the following report of the Veterinary Division for the fiscal year ending June 30, 1912:

Our work in the problem of determining the cause for ill effects from feeding cottonseed meal has consisted in making observations upon cattle, swine, rabbits and guinea pigs fed upon cottonseed meal, whole and modified.

The observations made were in looking for clinical symptoms in the living animals, the post-mortem lesions in those dying from effects of cottonseed meal and the histological changes in tissues taken from such carcasses.

The Animal Husbandry Division fed some thirty-five head of steers rather heavily upon cottonseed meal from December 1, 1911, to April 5, 1912, on an average about 7.5 pounds per steer for 127 days. No ill effects whatever were observed. A yearling calf weighing at beginning 175 pounds and at the end 247.5 pounds was fed 2.5 pounds daily, making a total of 702 pounds fed from October 6, 1910 to July 9, 1911, when it died. There was no gain in weight after first four or five months.

While showing some unthrift from the start, symptoms of disease were not conspicuous until about ten days before death. Symptoms consisted of not eating heartily, looking rather puny and becoming very weak and docile. There were gritting of teeth, rather noisy breathing and softened fæces.

Nine days before death, respirations were 100, pulse 85, and temperature 103.7 degrees F. Hæmatokrit reading of blood was 38 per cent and hæmoglobin was 80 per cent.

The symptoms in thirteen hogs fed cottonseed and cottonseed meal were observed from only a few minutes to four or five days before death. These consisted of loss of appetite, weakness, unsteady gait, more or less blindness and some difficulty in breathing. The hogs in most cases would finally get down unable to rise and lie there in a more or less comatose condition for a few hours to two or three days before dying.

The principal lesions found on autopsy of the calf consisted of slight excess of serous fluid in both abdominal and thoracic cavities, and considerable irritation of the intestines as indicated by marked injection of their mesenteric and visceral blood vessels. The fourth stomach contained considerable sand and gravel, indicating a depraved appetite. The lymph nodes were not found congested, as frequently reported by ourselves and others in cottonseed poisoning. The liver and kidneys showed some congestion. The lungs showed congestion, hepatization and some œdema. The external blood vessels of the heart were injected; a small thrombus and considerable firmly clotted blood were found within the heart.

The autopsies upon seven hogs dying from the effects of cottonseed meal revealed the following lesions:

- 5 of the 7 showed excess abdominal fluid;
- 6 of the 7 showed excess pleural fluid;
- 6 of the 7 showed irritation of mucous membrane of stomach;
- 4 of the 7 showed congestion of lymph nodes;
- 6 of the 7 showed œdema of lungs; and
- 5 of the 7 showed thrombi (antemortem clots) in heart.

The autopsies upon fifty rabbits revealed the following lesions:

- 36 of the 50 showed excess of abdominal fluid;
- 14 of the 50 showed excess of pleural fluid;
- 46 of the 50 showed some irritation of stomach;
- 43 of the 50 showed some irritation of intestines;
- 27 of the 50 showed thrombi (ante-mortem clots) in heart;
- 10 of the 50 showed œdema of the lungs; and
- 20 of the 50 showed congestion of the lungs.

In some cases it was evident that the lesions were not due to the effects of the cottonseed meal.

The autopsies upon two guinea pigs revealed the following lesions:

- 1 of the 2 showed excess of abdominal fluid;
- 1 of the 2 showed some irritation of mucous membrane of stomach;
- 2 of the 2 showed injection of mesenteric and visceral blood vessels of intestine.

No histological examination was made of any tissues from animals dying the past year of cottonseed meal poisoning. Examinations were made, however, of tissues preserved from cases collected during the first year's work (1908-1909).

Forty-three examinations of such tissues from swine were made consisting of 9 kidneys, 9 spleens, 7 livers, 7 lungs, 4 aortæ, 6 hearts and 1 voluntary muscle.

Nineteen of the forty-three sections showed nothing noticeable, leaving only 24 showing alterations. Among the 19 showing nothing were 7 spleens, 1 liver, 3 lungs, all 4 aortæ, 3 hearts and the voluntary muscle.

Of the 24 showing microscopical lesions:

- 4 kidneys showed hyperæmia;
- 6 livers showed hyperæmia;
- 2 kidneys showed hemorrhage;
- 1 heart showed hemorrhage;
- 4 livers showed hemorrhage;
- 2 kidneys showed inflammation;
- 4 lungs showed inflammation;
- 1 heart showed inflammation;
- 2 sections showed necrosis;
- 2 sections showed fatty degeneration;
- 1 section showed fatty infiltration;
- 3 sections showed disintegration; and
- 2 sections showed fragmentation.

Of the kidneys of 2 guinea pigs 1 showed nothing, and the other hyperæmia.

Of the livers of 3 guinea pigs 1 showed nothing, 1 hyperæmia, disintegration and fatty degeneration, and 1 inflammation. The heart of one guinea pig showed nothing.

Manuscript for a bulletin on "Some of the Infectious and Parasitic Diseases of Animals Prevalent in North Carolina" has been prepared. It includes two or three non-infectious diseases possessing some features common to the infections.

Numerous inquiries from farmers and others have been answered as well as laboratory examinations have been made of feeds, body tissues, samples of milk and parasites.

Respectfully submitted,

G. A. ROBERTS,
Veterinarian.

DIVISION OF PLANT PATHOLOGY AND BACTERIOLOGY.

I submit herewith a report of the Division of Plant Pathology and Bacteriology for the year ending June 30, 1912.

During the fiscal year Dr. F. L. Stevens, who had been in charge of the division since its organization as such, resigned to become Dean of the Agricultural College of Porto Rico. Mr. Guy West Wilson was acting head of the division from January 1 to March 15, when the writer assumed charge. This report is largely on work already in progress at that time.

Plant Pathology.—The studies on a Rhizoctonia disease of buckwheat have been continued.

Several apple diseases have been investigated, particularly a canker caused by Nectria, the disease known as Thelephorose, the orange leaf rust or cedar rust, and the bacterial twig blight. Reports on the first three appear elsewhere in this report.

A general survey of cruciferous crop diseases in the state was made preliminary to a detailed study of such diseases. It seems that Fusarium wilt, bacterial black rot, Phoma wilt, and club rot, are the most serious diseases of such crops.

Granville tobacco wilt investigations have been carried on along the lines already in progress.

The Plant Disease Survey in coöperation with the Bureau of Plant Industry of the U. S. Department of Agriculture, has been continued. Numerous inquiries about the identity and treatment of crop diseases have been answered.

By request, the writer attended a hearing of the Committee on Agriculture of the House of Representatives, in support of an appropriation that would provide for effective search for the chestnut bark disease in North Carolina and other states, in coöperation with the Bureau of Plant Industry.

Breeding for Disease Resistance.—Breeding of watermelons for resistance to Fusarium wilt has been continued, during 1911 in coöperation with the Bureau of Plant Industry of the U. S. Department of Agriculture, and during 1912 by this Division alone. The melons are satisfactorily resistant to the disease, and of excellent quality; but greater toughness of rind must be secured before the melons will be satisfactory for shipping.

Soil Bacteriology (in coöperation with the Division of Chemistry).—Report on phases of this work completed in 1911 are published elsewhere in this report under the authorship of F. L. Stevens and W. A. Withers. The bacteriological side of the work was largely suspended during the winter months. In June it was actively resumed, and Mr. W. F. Pate of the Chemistry Division, was temporarily detailed to assist in it. For the present this work includes chiefly a study of the bacteriological activities in the soils of 18 experimental plots on the Station Farm that have received different fertilizer treatment or have had different crop rotations for a number of years.

Respectfully submitted,

H. R. FULTON,
Plant Pathologist and Bacteriologist.

DIVISION OF ENTOMOLOGY.

I have the honor of transmitting herewith, the report of the Division of Entomology for the fiscal year ending June 30, 1912.

During this time Mr. R. I. Smith was Entomologist from July 1, 1911, to December 15, 1911. The writer assumed active duties on February 1, 1912.

During the past year Mr. Smith devoted practically all of his time to a study of the Corn Bill Bug, *Sphenophorous callosus*, and the Little Grass Bill Bug, *Sphenophorous parvulus*.

The common corn bill-bug, *S. callosus*, which causes practically all the so-called bill-bug injury in the State, has received most attention but the project was so stated as to allow for an investigation of all the related species of *Sphenophorus*.

Only three other species have been discovered in the course of this work, namely, *S. parvulus*, *S. venatus*, and *S. cariosus*, and no life history study of the last two mentioned has yet been undertaken. All these, however, are serious pests in some States and they should, as time permits, be given careful attention under this project.

The grass bill-bug, *S. parvulus*, is fairly numerous in the vicinity of West Raleigh, and doubtless in other sections of North Carolina. The record of one fertile female collected May 19, 1911, forms an interesting biological study, for her full egg-laying record was secured for the season, and her progeny were secured and reared to the adult beetle stage, while larvæ of the second generation were also reared to maturity but no adult beetles of that generation were secured. The work indicates that a partial second generation usually occurs, but whether or not the numbers are sufficient to be of importance, it is impossible to say at this time. As all the rearing records were carried out with eggs and larvæ from a single female collected May 29, and only one reared specimen laid eggs for a second generation, it does not seem advisable to assert that a second generation is a common occurrence. However, the writer believes this to be the case with *S. parvulus*, and with *S. callosus* also, but in even more exceptional cases.

The life history studies of *S. callosus* are included in the records on all phases of the life history of this insect. This includes the feeding and egg-laying habits of the beetles, feeding habits and development of the larvæ, formation of pupal cells and duration of pupal stage, emergence of adult beetles and the habits of the beetles after maturity.

The time of the present Entomologist since his appointment on February 1, last has been devoted almost exclusively to a consideration of the two Adams Fund Projects,—the Corn Bill Bug and the Gloomy Scale.

More emphasis has been placed upon the study of the Corn Bill Bug in the hope that this project could be closed this year, but new developments seem to make this undesirable. Many details of the life history have been worked out in the field, and these have been found to agree in the main with the details previously ascertained by Mr. Smith in the insectary. In addition to corroborating Mr. Smith's work many new

facts regarding the habits of the adults in feeding, mating and egg-laying have been established for the first time.

Some progress has also been made in a study of practical farm methods for the control of this insect. But these will require observations covering a period of several years before they can be fully established.

Marked progress on the Gloomy Scale project was prevented owing to the frequent absences of the Entomologist on the Corn Bill Bug work. The life history of this insect from February to June has been gone over and checked up with our previous knowledge and several new host plants have been added to the list.

Mr. Pool of the Civil Engineering Department of the College has kindly furnished us with a map showing the location of all of the trees on the campus which will be of great service in the study of host plant relations. In addition, the J. Van Lindley Company, Pomona, N. C., and the John A. Young Nursery Company, Greensboro, N. C., have furnished us with several samples of all the varieties of maples grown in North Carolina for shade purposes.

The Entomologist has devoted some time to giving advice for the control of insect enemies of shade trees in cities and towns. As our cities and towns increase in population the problem of growing shade trees becomes increasingly apparent. Frequently the trees are injured to such an extent by electric wires, by sewers and gas mains and by filling and grading that they are especially susceptible to the attacks of insects. During the past year many fine trees in Charlotte, Greensboro, Durham and Raleigh have been either killed outright by the attacks of insects or have been so severely injured as to be worthless for shade purposes. This is a phrase of the entomological work of the State that has received very little attention in the past, but that is demanding more and more attention every year. The most unsatisfactory feature of this work is the fact that the Entomologist is not usually consulted until the tree is practically dead or so near dead that remedial measures would be of no avail. The only possible correction for this state of affairs is the education of our people to a better appreciation of the beauty and utility of shade trees together with a series of publications setting forth the essential facts of the life history and control of the more injurious insect enemies of our shade trees.

NOTES ON INSECTS OF SPECIAL INTEREST.

The Cotton Leaf Worm has been unusually numerous this past fall, resulting in causing considerable alarm among cotton growers, who did not know that the worms can not pass the winter in this State, and, therefore, are not liable to occur again in injuring numbers for several years.

The Corn Stalk Borer has been more numerous and destructive than usual. For the last four years I have observed a gradual increase in the corn stalk borer damage. This year over 60 per cent of the plants were infested in many corn fields. I have never seen a field entirely free from this pest, and it now represents one of our most serious corn pests. The best remedy lies in plowing out and burning the corn stubble dur-

ing late fall. Next to this, late fall or winter plowing, without burning the stubble, is partially effective. The borers live during the winter in the tip of the tap root and in no other situation, hence the reason for these suggested remedies.

Corn Weevil injury has been reported frequently, seemingly more so than during past seasons. Farmers need to prepare a means for successfully fumigating with carbon bi-sulphide. Many copies of Bulletin 203 have been mailed to farmers who have reported corn weevil injury.

The past spring has afforded the usual number of pests of the crops grown on the farms and in the gardens and orchards of the state, and several insects of local importance have demanded the attention of the Entomologist from time to time. Some of the more important of these are the Native Cabbage Worm, Cabbage Louse, Harlequin Bug, Cutworms, Elm Leaf Beetle and Plum Curculio.

There has been some correspondence which it seemed more advisable to handle from this office than to refer to the State Entomologist's office, although that office now takes care of the bulk of the Entomological correspondence of the State.

Respectfully submitted,

Z. P. METCALF,
Entomologist.

DIVISION OF POULTRY HUSBANDRY.

Herewith I beg to submit a report of the Poultry Division for the year ending June 30, 1912.

Of the proposed experiments it was only possible to carry on those in relation to feeding for egg production.

These experiments were begun January 1 with eight pens of ten females each and are being conducted on the same lines as those of previous years, with the exception that cottonseed meal has been left out of all rations as the experiments of former years seemed to justify the same.

As now fed the rations in addition to 2 parts whole corn, 1 part wheat, fed at night to all units alike, are as follows:

Pens 20 and 26—4 lbs. corn meal; 4 lbs. wheat bran; 4 lbs. ground oats.
 Pens 21 and 27—4 lbs. corn meal; 4 lbs. wheat bran; 2 lbs. bone meal.
 Pens 22 and 28—4 lbs. corn meal; 4 lbs. wheat bran; 2 lbs. beef scrap.
 Pens 23 and 29—4 lbs. corn meal; 4 lbs. wheat bran; 2 lbs. bone meal and 2 lbs. beef scrap.

Pens 20, 21, 22, 23 have for range an ample yard set in Bermuda sod.

Pens 20, 27, 28, 29 have a much larger yard ($\frac{1}{2}$ acre each) on which it was intended to keep growing some green crop, such as winter oats until same could be harvested and followed by corn for summer. But owing to the dry weather prevailing during the summer the land could not be broken for corn.

In this way the relative merits were to be tested, of limited range on permanent sod versus much larger range on growing green crops.

To date the egg yield has been as follows:

Limited range.
 Pen 20—30 6-12 doz.
 Pen 21—53 9-12 doz.
 Pen 22—38 2-12 doz.
 Pen 23—48 1-12 doz.

Large range on growing crop.
 Pen 26—27 3-12 doz.
 Pen 27—62 doz.
 Pen 28—29 8-12 doz.
 Pen 29—40 8-12 doz.

During this time each pen has consumed feed for the value as follows:

Pen 20—\$7.47	Pen 23—\$8.41	Pen 28—\$6.70
Pen 21—\$6.70	Pen 26—\$7.71	Pen 29—\$5.44
Pen 22—\$7.10	Pen 27—\$8.00	

Reckoning the eggs produced at 25 cents per dozen, the results in profit and loss to date are as follows:

Pen 20—\$0.15 $\frac{1}{2}$ profit.	Pen 26—\$0.91 loss.
Pen 21—\$6.73 profit.	Pen 27—\$7.50 profit.
Pen 22—\$2.44 profit.	Pen 28—\$0.71 profit.
Pen 23—\$3.61 profit.	Pen 29—\$4.22 profit.

The pens showing the greatest profits, 21 and 27 had bone meal only as animal food and those showing the second best, 23 and 29, had beef scrap in addition to the bone meal. The third pair, 22 and 28, had scrap alone, while the low pair, 20 and 26, had no animal food.

From the data at hand it might be inferred that beef scrap was not as important an ingredient as is generally conceded and that bone meal may be a cheaper source of animal food supply.

The experiments for the ensuing year have in mind the further study of this matter.

During the past year two double and one single pen open-front houses have been completed.

The past winter being a severe one, the merits of this style of house were put to a severe test and except where the back was not entirely storm proof the stock came through in excellent shape. In two cases where cracks were left at the junction of back and eaves the male birds lost the tips of their combs by freezing.

The interest in thoroughbred poultry throughout the State continues to grow. The demand for eggs for hatching and breeding stock being more than sufficient to take all surplus.

Respectfully submitted,

THOS. H. TAYLOR,
Poultryman.

RECEIPTS AND EXPENSES.

NORTH CAROLINA AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH THE
UNITED STATES APPROPRIATIONS, 1911-1912.

DR.

To receipts from the Treasurer of the United States, as per appropriations for the fiscal year ending June 30, 1912, under Acts of Congress, approved March 2, 1887, and March 16, 1906:

Hatch Fund	\$15,000.00
Adams Fund	15,000.00

CR.

	<i>Hatch Fund.</i>	<i>Adams Fund.</i>
By salaries	\$5,321.58	\$11,248.47
Labor	2,689.29	1,241.43
Postage and stationery.....	467.12	227.60
Freight and express.....	156.60	65.95
Heat, light and water.....	79.90	33.79
Chemical supplies	13.47	251.48
Seeds, plants and sundry supplies.....	670.33	127.07
Fertilizers	1,132.21	217.81
Feeding stuffs	2,245.97	452.38
Library	26.29	134.40
Tools, implements and machinery.....	721.79	145.97
Furniture and fixtures.....	90.66	345.62
Scientific apparatus		53.30
Live stock	213.40	76.55
Traveling expenses	396.39	73.95
Contingent	25.00	
Buildings and land	750.00	304.23
Total.....	\$15,000.00	\$15,000.00

We, the undersigned, duly appointed auditors of the corporation, do hereby certify that we have examined the books and accounts of the North Carolina Experiment Station for the fiscal year ending June 30, 1912; that we have found the same well kept and classified as above, and that the receipts for the year from the Treasurer of the United States are shown to have been \$30,000, and the corresponding disbursements \$30,000; for all of which proper vouchers are on file and have been by us examined and found correct, thus leaving nothing.

And we further certify that the expenditures have been solely for the purposes set forth in the Acts of Congress, approved March 2, 1887, and March 16, 1906.

(Signed)

W. B. COOPER,

M. B. STICKLEY,

Auditors.

(Seal.)

Attest: A. F. BOWEN, *Custodian.*

SCIENTIFIC AND OTHER PAPERS

ECONOMIC VALUE OF CORN SUCKERS.

BY C. B. WILLIAMS AND W. E. ETHERIDGE.

The removal of suckers from the corn plant soon after their development is quite common with farmers throughout the Southern States. This practice is largely based upon a widespread notion among corn-growers that if the suckers are allowed to remain they will not only sap the energies of the main plant by taking away from it much needed plant-food, but in return will yield little or no grain and what is produced being of an inferior quality. Many farmers even think that suckers when they yield grain at all bear only a few imperfect kernels on the tassels.

Four years ago the North Carolina Experiment Station began field experiments designed to determine, among other things, if the common belief that the removal of suckers proved beneficial to the crop was true or not. In the studies sixty-eight varieties of corn were used in 1908; sixty-one in 1909; forty-nine in 1910; and eight in 1911. During the first three years each variety was grown, with and without suckers, under four different conditions of soil fertility and of distancing of the hills of corn in the row; and in the last year, the varieties with and without suckers, have been experimented with under seven different degrees of fertility of the soil. The gradation in the productivity of the different sets has been held by the use of stable manure and commercial fertilizers. The results and deductions made use of in this paper are taken from the results of these investigations.

CHIEF FACTORS INFLUENCING THE PRODUCTION OF SUCKERS.

Soil fertility, distance between plants in the row, variety and season are the principal factors influencing the number of suckers produced per plant. Ordinarily, chief controllable of these are soil fertility and variety.

Effect of Soil Fertility.—Under favorable seasonal conditions with a definite number of square feet given to the growth of each plant, the number of suckers developing per plant with the same variety will increase as does the productivity of the soil.

As an average of the results of 1910 with forty-nine varieties, 14.1 times as many suckers developed per acre on land producing 44.8 bushels of shelled corn as were produced where a yield of 12.3 bushels were secured; while in 1911 with eight varieties there were 6.4 times as many where the yield was 35.6 bushels as when 17.5 bushels were produced. Again in 1911, on land producing twice as great yield of shelled corn per acre as other land all the varieties averaged 6.5 times as many hills bearing suckers as did the less productive land.

Effect of Different Distancing of Plants.—It was found in 1908 that when corn was grown in four-foot rows on land producing an average

of 28 to 32 bushels of grain per acre that 48 per cent higher proportion of the stalks produced suckers and 73.4 per cent more suckers were developed per acre when the spacing of the plants in the row was 30 inches than when the distance between hills was 20 inches. In 1909 and in 1910 with the average yields running 38 to 39 and 41 to 48 bushels per acre the proportion of sucker-bearing stalks was 15.9 and 110 per cent higher respectively, and the yield of suckers 14.3 and 71.4 per cent more at 30-inch than at 20-inch spacing of the hills in the row. On the poorer land used in the experiments, where the yields ran from 9 to 16 bushels of grain per acre, the proportion of sucker-bearing stalks was higher by 29.8 per cent in 1908, 43.5 per cent in 1909 and 650 per cent in 1910 at 30-inch than at 20-inch spacing; while the percentages increase of suckers on this land for these years were 100, 7.8 and 471 per cent more respectively at 30 inches than at 20 inches between hills in the row.

It should be remembered that as the number of suckers produced is influenced to a considerable extent by the fertility of the soil, the more square feet given to each plant on good soil or the wider the space between hills, the distance between rows remaining the same, the higher the proportion of sucker-bearing hills and the greater the number of suckers may be expected to develop per acre, when the same kind of seed are planted on uniform soil.

Effect of Variety.—The kind of variety plays an important part in determining the number of suckers produced per acre under any given condition. In the results of 1908, of 1910 and of 1911, the prolific varieties produced 300, 130.5 and 25.1 percentages respectively more hills bearing suckers than did the one-eared varieties when the two types in each year were grown under identical conditions. In 1911, Brake's a well known single-eared variety, was exceeded in the production of sucker-bearing hills 54.7 per cent by Biggs' Seven-eared, 64.5 per cent by Sanders' Improved, 52.6 per cent by Weekley's Improved, 32.3 per cent by Cocke's Prolific and 29.7 per cent by Hickory King when all were grown on uniform land. As an average of three years' results, the prolific varieties produced 2.6 times a greater percentage of suckers that bore ears as did the one-eared varieties.

Effect of Season.—Other factors being the same, the more unfavorable the season is for the plants, especially during the early part of the growth of the corn, the smaller will be the number of suckers produced per acre. Under favorable weather conditions during the first half of the growing period with corn planted on fertile land, a large development of suckers will under most Southern conditions take place, and these may in some cases with a very dry July and August depress the yield of grain per acre under what it would be were the suckers taken off at the usual time of removal.

SOME CHARACTERS AFFECTED BY REMOVAL OF SUCKERS.

In these investigations, it has been observed that the removal of suckers from the stalks has had, in most cases, a decided influence upon the different characters of the corn plant which contribute to its eco-

nomie value, such as prolificacy; size of ears; percentage of grain; yield of grain and of stover per acre, etc.

Effect on Prolificacy.—As only results from two years' work (1909 and 1911) have been obtained in determining the effect of the removal of suckers upon prolificacy in ears, of course definite deductions can not be made. The results thus far secured, however, are quite striking in showing that for a good average season the lessening effect in prolificacy by the removal of suckers.

In 1909 there was an average reduction of 46.3 per cent in the number of ears produced per stalk by the corn on the plat from which suckers were removed under what they were on the corresponding plat where the suckers were allowed to develop; but in 1911 there was a reduction of the average number of ears per stalk by 7.4 per cent by allowing the suckers to remain. It should be remembered, however, that the results of the past year were secured under weather conditions that were abnormal and which were as unfavorable to suckers performing their proper functions as would probably ever occur in this latitude, as the season was favorable during the early part of the growth of the plants for the development of a large number of suckers and later on in the growing season it was very dry and the plants suffered greatly for lack of a sufficient moisture supply. For weeks in July and August the leaves of the plants were rolled. It is natural to suppose that under such adverse conditions that the plants having a large development of suckers would suffer much more than did those from which the suckers were removed, but even with all this disadvantage there was not but 7.4 per cent reduction in the number of ears per stalk. As an average of three years' results (1908, 1909 and 1910) with corn planted in four-foot rows on land averaging in yield 37.7 bushels of grain per acre, 18.1 per cent of the suckers produced ears with the hills 30 inches apart in the row and 9.5 per cent at 20 inches. On land averaging 13.7 bushels, 2.1 per cent of the suckers bore ears at 30 inches and 1.5 per cent at 20 inches. It will be observed from this data that from 6.3 to 8.6 times as great percentage of the suckers bore ears on the good land as on the poor land.

Effect on Size of Ears.—With the exception of the results of 1909, the removal of suckers has tended generally to the production of ears by the main stalk of slightly greater length and of diameter, the average being 3.2 per cent in length and 0.8 per cent in diameter. This would seem to be what would be expected since it was found that with a favorable season the prolificacy was increased by the unmolested development of suckers.

Effect on Yield of Grain.—The weight of evidence thus far is that on an average with the kinds of land used and the types of varieties experimented with there is a slight reduction in the weight of grain per stalk by the removal of suckers. There are many varieties, however, in some or all of the different years that have not conformed to the general average of all the results.

Effect on Percentage of Grain-to-Cob.—For this character, the results of all the tests are in quite marked conformity and present strong

evidence that the removal of suckers from the stalks slightly reduces the percentage of grain to cob. On good land, as an average of the results of 1909, of 1910 and of 1911, there was a reduction of 0.47 per cent in the percentage of grain-to-ear by taking off the suckers. To appreciate this average difference, it should be remembered that ordinarily the relation between grain and cob is quite constant, being probably less affected by environment than most other characters of the corn plant. During a favorable season, it has been noticed that there was generally a gradual decline, slight but constant, in the percentage of grain-to-cob as the fertility of the land grew less.

Effect on Stover.—With a few individual varietal exceptions all occurring during the very dry season of 1911, all the experiments have shown on an average without exception that sucker-bearing plants are heavier producers of stover than are plants from which the suckers were pulled in the early stages of their development. As an average of three years' results on the best land where the suckers were chiefly produced, the depression in yield of stover per acre by removal of suckers has been found to be 29.7 per cent; notwithstanding the fact that the growth of the suckers diminished the average height of the stalks 3.9 per cent.

Effect on Combined Value of Grain and Stover.—By assigning a value of 80 cents per bushel for grain and \$8.00 per ton for stover, it has been found that, on an average of three years' results on the better grade of land, that there was a diminishing by 17.7 per cent of the combined value of the grain and stover by the removal of suckers from the stalks. Only in one case with the sets in the three years was there a greater value of grain and stover taken together. This occurred in 1910, and may have been due to the greater damage to the sucker-bearing portion inflicted by a severe wind storm occurring during August of that year. However this may be, it is quite striking that, on an average of three years' work with eight to sixty-one varieties in each test, more than one-seventh of the value of the corn crop was sacrificed by the removal of suckers. From these data it would appear that hundreds of thousands of dollars must be lost annually by the farmers of the Southern States in labor and in yield by not allowing suckers to develop to maturity on their corn plants.

ECONOMIC IMPORTANCE OF CORN SILAGE IN SOUTHERN BEEF PRODUCTION.

By R. S. CURTIS.

There are three distinct agents which must be active in developing the Southern beef cattle industry. First, the South must have better breeding stock applicable especially to sires or heads of the herd. This improvement is dependent, however, in part on the eradication of the cattle tick. Second, a liberal education is necessary in the fundamentals of live stock feeding as pertaining solely to the proper administration of feed. Third, education of farmers and stockmen regarding the necessity of producing more and better home-grown feeds. It is the latter phase of the subject in part on which the writer hopes to bring out some information concerning the economic importance of corn silage in the Southern beef cattle industry.

While this is not a new topic for discussion, it is one of vital and rapidly increasing interest to every farmer who keeps dairy or beef animals. Ten years ago the latter part of the statement would have received no serious consideration for the sole reason that silage had not been extensively tried in the beef cattle ration and feeders generally were loath to give the matter serious thought. However, high priced land and labor and expensive feed-stuffs have compelled the farmer to get more units of value from his crops. The introduction of corn silage as a maintenance ration for breeding stock and a fattening ration for beef cattle has probably done more toward solving the high cost of feed than any other agent. This is especially true, however, during the winter maintenance period. One of the hardships or apparent losses which every breeder or producer of beef cattle must undergo is the proposition of economically wintering a herd of beef cows for the sole purpose of producing a crop of calves the following spring.

In consideration of the production of young cattle, it is well known even in the best grass sections that the winter season is the period of greatest maintenance cost and the one producing the least increase in the value of the animal. This is because the cheap feeds supplied by good grass pasture of necessity become depleted in growth in the fall season and it is for this reason that a cheaper feed must be supplied and one which will produce an increase in the weight and value of the animal if possible. The old system of keeping cattle through the winter or dormant period on dead corn stalks or cheap ill-cured grass, straw or hay, can not compete with the new system of providing succulent feeds liberally in the ration. Cattle wintered in the former manner will in the majority of cases not only lose in weight, but will also be forced to stop their natural body growth which if ever regained, will be at double the expense of feed and labor. This continuous increase in gain and value is applicable both in breeding and in fattening beef animals.

In the Western feed lots, the question of getting finish has not been a difficult problem when the cattle were handled by experienced feeders because the feeds were available to produce the desired condition and the

art of feeding has been mastered. However, even under their conditions, silage now forms a prominent place in the ration. It has brought pasturage effects to non-pasturage periods and has, therefore, brought closer together the producer and the feeder, which it will be instrumental in doing under Southern conditions. At first used most extensively by feeders in supplementing winter maintenance rations, silage has gradually found a permanent place in the finishing ration for beef steers. It has not only materially reduced the cost of winter maintenance but has made possible a conditioning of cattle during this period that will compare favorably with the advantages of summer pasture grasses. A recent experiment at the Pennsylvania Station shows most emphatically the practicability of wintering beef breeding cattle on corn silage, whereas, before the use of dry roughage feeds made the wintering period costly and oftentimes impracticable. This experiment is cited primarily because of its practical bearing on Southern conditions and because of the significant character of the work. Briefly discussed, ten Shorthorn and ten Aberdeen Angus cows were placed in winter quarters on a ration of one pound of cottonseed meal daily and all the corn silage the cows would eat. The average amount of silage consumed was 55 pounds per animal daily. The Shorthorn cows were thin at the start but improved steadily during the winter, gaining a total of 238 pounds in 140 days, or an average of 1.7 pounds daily. The Angus cows were in better flesh and made somewhat less improvement, their gain being 151 pounds in the same period, or an average of 1.1 pounds daily. The silage thus proved to be even more than a maintenance ration when supplemented with one pound of cottonseed meal. This gain would have been not only impossible if the cottonseed meal had been supplemented with a dry roughage feed, but the condition of the cattle in the spring would not have been comparable. The average net cost of keeping each cow was slightly over \$8.00, while the average increase in value was \$33.00. A significant factor in this work showed that silage fed cattle do not need extra shelter when fed on corn silage, a common belief among some cattle men.

This same method of feeding can be followed as well or better in the South, where cottonseed meal is the chief available concentrate and corn silage of excellent quality can be produced. The stimulus which is being furnished for the production of corn in the South adds strength to the argument for using more of this product in the form of silage. The loss of leaves, the most succulent and nutritious part of corn when cured as fodder, places silage in the lead not only in quantity of feed but from experiments and practice, in efficiency and profit.

Experiments during the past three years at this Station show that one and one-half pounds of corn silage is equal to one pound of cottonseed hulls in feeding value. These experiments were conducted with beef cattle during the winter season, hulls and silage being the only roughages fed during the experimental period. During this time cottonseed hulls have sold from \$6.00 to \$12.00 per ton while the usual rating on corn silage is \$4.00 per ton. Not only is this difference in value markedly apparent, but corn silage is a home-grown product,

while cottonseed hulls must be purchased practically at a cash outlay by the farmer. Aside from these differences in cost the use of silage actually increases the efficiency of a breeding animal and the final value of a fattened beef animal. These statements are substantiated, the former by the Pennsylvania Station and the latter by the figures from this Station, showing the average net profits for the three years in steer feeding to be \$9.00 per head on the silage fed cattle and \$3.85 per head on the hulls fed cattle. In addition to this the silage fed cattle were rated each year from \$0.25 to \$0.50 per hundred above the dry fed steers, which with the cheaper gains made was responsible for the larger profit.

Another striking fact brought out in these experiments was the effect of corn silage in prolonging the period through which profitable gains can be made. The lot fed cottonseed hulls for roughage made the largest increase in weight during the first two months, but during the third month these cattle dropped to .54 of a pound and in the fourth month to .01 of a pound of gain per day. In all other cases the daily gains were made much more uniformly until the close of the experiment. In every case the silage fed cattle made greater gains during the fourth month than was made during the third month by the lot fed cottonseed hulls as the roughage. The average daily gains of the steers as a whole from the time they were placed on feed until sold was a mere fraction under two pounds per day. The total average gain per steer for the 166 days was 322.6 pounds. It is important to note that during the experimental period the average daily gains made by the lot fed corn silage did not lack materially in making the average daily gain made by the entire number of steers during the total feeding period. The average gain during the experimental period for the cattle fed cottonseed hulls was 1.28 pounds and for the cattle fed corn silage 1.70 pounds. This represents approximately 25 per cent increase in the gain of the silage fed cattle over those fed cottonseed hulls.

Recent experiments at the South Carolina Station designed on the same plan as followed by the writer show that steers fed corn silage as a sole roughage with cottonseed meal made not only larger but cheaper gains, and the cattle took on a better finish than steers fed either corn stover or cottonseed hulls. The cattle fed on corn stover made better gains than the lot fed on cottonseed hulls and at less cost. The cottonseed meal required to make a pound of gain on the steers fed silage was 3.22 pounds; on the stover fed steers 4.57 pounds; and the cottonseed hulls fed steers 4.69 pounds. The most interesting factor is the cost per pound of gain which from a relative standpoint corresponds very closely to the average results obtained by the writer. The silage fed cattle made gains at a cost of 6.4 cents per pound; the stover fed cattle 9.82 cents per pound, and the hulls fed cattle 11.9 cents per pound. The profit on the cattle, including the manure, was for the silage fed cattle, \$7.20 per head; for the stover fed cattle, \$2.50 per head, and for the hulls fed cattle it was a negligible amount.

The writer believes the South to be especially fortunate in having throughout the Southern States a campaign for more and better corn,

and for the extended use of the silo. It is believed that through the wise use of silage, cottonseed meal, our dependable concentrate will be increased by one-quarter of its absolute value and the extra finish obtained on the cattle will under normal conditions bring a profit where oftentimes a loss is sustained.

Upon examination under other conditions it is found that extensive experiments at the Indiana Station have shown conclusively that corn silage in a ration of shelled corn, cottonseed meal and clover hay, gave considerably larger gains, cheaper gains, and a greater profit per steer than cattle fed on any other ration. While the conditions under which these experiments were conducted were entirely different from those in the South, the work furnishes additional evidence of the value of corn silage, whatever the supplementary feeds may be. Workers at various other stations have cited similar facts concerning the use of this product. Contrast with the results previously given, the old system of using high priced and less efficient roughage feeds which with extreme care barely maintained the normal weight of the animal and more often a distinct loss in weight resulted. Such was the result of former management in many cases before the silo became a prominent factor in live-stock feeding.

From the experimental evidence at hand the writer figures that beef breeding cattle can be maintained 25 per cent cheaper on corn silage; and beef feeding cattle may be fattened 15 to 20 per cent cheaper. For the latter the extra finish acquired through the use of silage will be valued ordinarily at 10 to 15 per cent over the animal fed dry roughage. This fact has been established from two viewpoints. First, beef cattle fed on dry roughages during a feeding period of average length will actually make their gains at a considerably higher cost than cattle fed on corn silage alone or in combination with a dry roughage feed. Second, it has been definitely determined that cattle fed liberally on corn silage can consume safely from 20 to 25 per cent more cottonseed meal, which, as expected, will produce a characteristic finish of a higher value than is possible during the shorter feeding period. Cottonseed meal is not only less efficient with a dry roughage, but because of the shorter feeding period necessary when so fed, the feeder is unable to acquire the higher market condition required for top prices.

On the saving and efficiency basis established heretofore by the writer, the cost of winter maintenance for breeding stock would represent a saving to the South in feed based on its market value as follows: On the 12,500,000 breeding animals maintained the annual saving to the South would be \$37,500,000. On fattening stock based on a 15 per cent saving in feed and the greater efficiency obtained from the other feeds used, the saving would represent on 5,250,000 fattening animals \$23,625,000. The figures relating to breeding stock are based wholly on the financial saving, no consideration being taken of the enhanced value or the ultimately more satisfactory breeding condition maintained in the silage fed animals. Corn silage is an important factor in feeding beef cattle where a large quantity of cottonseed meal is fed daily. In the opinion of the writer this is an important factor,

since one of the things needful of correction under Southern conditions is a system of feeding whereby fattening cattle may be placed in a reasonably high market condition. No one factor with the exception of the cattle tick is more largely responsible for the failure to get profitable returns on beef cattle than the appalling lack of fat in cattle sent to the market. Just as long as the South follows a haphazard method in cattle feeding and fails to take advantage of scientific facts easily applicable in practice, just so long will she be compelled to patronize a local beef cattle market where prices seldom if ever reach above a mediocre level. Fat cattle will draw central market operators; lean cattle will keep them at home and force a glut on the small local concerns, which under such conditions becomes a menace to the whole cattle breeding industry.

While it is not possible for every cattle owner to equip himself at once with a silo it is believed that he cannot well delay the erection of such farm equipment. Although in some sections of the country such equipment is not as necessary as in the South, it will under any conditions bring non-pasturage areas, or dormant winter periods nearer to grass than any other farm or commercial feed yet placed on the market.

At first used in the dairy cow ration, silage is now considered largely indispensable by modern beef producers. While it even met with much opposition by the large majority of dairymen at first, it has now become a standard feed in caring for dairy, beef breeding and fattening animals. It has formed a connecting link with pasture grass from fall to spring where beef breeding cattle are maintained. This was originally responsible for its popularity. Its great value is now almost unmeasured in cheapening the cost of winter maintenance and in keeping the body in the natural condition which grass produces in the rapidly growing or fattening animal.

Henry of Wisconsin has, through experiments and far-sighted reasoning, placed silage in the rank which it now holds. It has been stated by him that while corn silage produces a watery carcass soft to the touch, this is considered of special importance where corn forms the main concentrated feed in steer feeding because it not only makes a hard dry carcass, but it burns out the system in the shortest possible time. It may well be said that the same condition will hold where cottonseed meal forms the chief concentrate in the ration. With silage or roots digestion is more nearly normal and the digestive tract will continue to work efficiently for a longer continuous period when silage is fed. This the writer has found to work out in practice in experimental cottonseed meal and corn silage feeding. It was on the basis of these facts which have been determined that the statement was made heretofore that a saving of from 15 to 25 per cent would be effective through the use of silage on breeding and feeding cattle. Whether the desirable results are brought about through active digestion of the other feeds or whether it is the nutritive value of the silage is the point at issue. The writer is of the opinion that it is the former factor which increases the efficiency of the cottonseed meal. It is stated by the authority previously mentioned that the tissues of the body being

juicy the whole system should be in like condition to permit of rapid fattening. It is recommended to use silage liberally, especially in the preliminary and early stages of the final fattening period. While it should be continued through most of the fattening period the amount fed should be decreased as the feeding period advances and more dry roughages should be substituted. This is to allow for the firming of the flesh and fat as marketable condition is acquired.

These statements are all entirely in accord with the results obtained at this and the other Stations mentioned. While the writer considers silage of value in any ration for beef cattle it is of special importance in the beef steer ration where the feeding period is to be continued for an excessive length of time when the cottonseed meal would have a tendency to burn out the active agents of digestion. While the increase in the use of corn silage for cattle feeding purposes may be slow broadly speaking, conservative, practical and experimental evidence point to the logic of its use wherever possible. Having its origin in the feeding of dairy cattle it has become a standard feed for all ruminating animals. Because of its meritorious properties for such animals in all stages of life it is firmly believed that silos will continue to be an established equipment on every successful Southern live-stock farm.

NOTES ON THREE LIMB DISEASES OF APPLE.

By GUY WEST WILSON.

NEW YORK CANKER.

History.—This disease first attracted attention in 1898 in the apple districts of New York, hence the name given above. More recently it has come to be known as the black rot canker in recognition of the identity of the fungus with that causing the black rot of the fruit.

Probably the New York canker was a serious apple pest for many years before its detection, but owing to the superficial resemblance of its cankers to those of sun scald the latter trouble was credited with all the damage.

Cause.—The New York canker is caused by a fungus known to botanists as *Sphaeropsis malorum*, Peck. This fungus is one of the more serious apple diseases of America, attacking all the above-ground parts of the tree, causing cankers on the trunk and branches, spotting of the leaves, and causing the black rot of the fruit.

Distribution.—As a fruit rot this fungus is known throughout North America east of the Rocky Mountains on the apple, pear and quince; while as a canker it occurs on all of these trees as well as on the hawthorn or red haw, and probably on other trees and shrubs as well. It also causes a leaf-spot of the apple and probably of the pear and quince. The fungus has recently been found in France, this being its first appearance abroad.

Symptoms.—This canker may attack any part of the tree, but it is most conspicuous on the larger limbs and even the trunks of mature trees. On the other hand twigs are often attacked (Fig. 1), and the young nursery stock may be killed. The cankers vary somewhat in appearance, due to the position upon the tree and the depth to which the fungus has penetrated. If only the twigs are affected the tips die and become covered with the black pustules which are characteristic of the disease. If the larger branches are attacked and the fungus penetrates only into the bark, the diseased area assumes a swollen appearance, and the bark becomes somewhat roughened. Such areas are of little consequence and do slight damage to the tree since the fungus soon dies.

In severe cases true cankers are formed. These may be only a few inches in extent, or they may be several feet long, involving one side of a branch, or in extreme cases completely encircling it. The bark is first thickened and roughened and eventually killed, and a subsequent shriveling and cracking of the bark results in a depressed area on which appear numerous characteristic small black pustules, which are the spore-producing bodies of the fungus. The growing region of the tree, or cambium layer as it is called, is infected and killed so that the canker affects not only the bark but the wood as well. In time the dead bark may break away leaving the wood exposed.

If a branch is completely girdled it of course dies, but if only one side is affected it may live for several years and continue to bear fruit.

However, its vitality is weakened and its productiveness lessened. The exposed wood turns blackish and is conspicuous from a distance; and such a canker gives wood decaying fungi a good place to find lodgment and complete the work of destruction.

It has been proven by experiments that at least under certain conditions this fungus has the power of entering healthy apple bark and causing a disease of otherwise healthy trees. The first attack is usually in the spring and is shown by discolored areas of bark which enlarge till midsummer, when there is formed a definite line of separation between the healthy and diseased bark. Later spore-bearing pustules are formed. The fungus frequently lives in the bark over winter and resumes growth the next season.

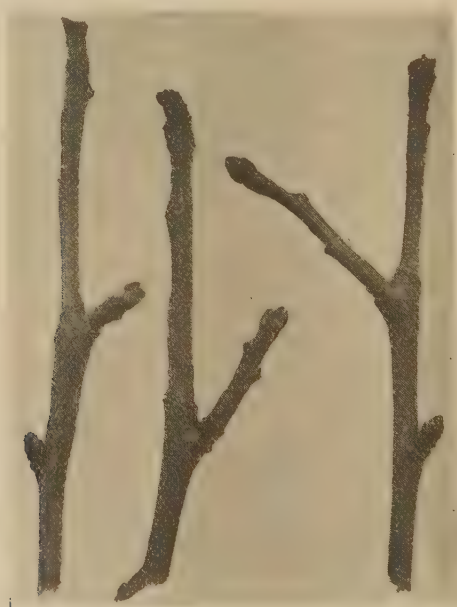


FIG. 1.—New York Canker on apple twigs, showing minute pustules of the fungus over the deadened bark. Slightly reduced.

Far more serious than the power of penetrating the bark is the development of this fungus as a wound parasite. While the fungus is able to penetrate the outer layers of bark, the inner layers seem to resist its attacks and prevent its reaching the cambium layer, in which event the deep cankers are not formed. If some other agency first breaks the bark the fungus gains entrance through the wound to the cambium and wood and an extensive canker is developed. Frequently several cankers appear close together, but each has developed from a separate infection as the mycelium does not travel through the wood.

Resistant Varieties.—That certain varieties are much more resistant to the disease than others is well known, yet most of the available lists of varieties and the effects of the disease are made from data obtained

in more northern states. The list usually given shows that Spitzenburg and Twenty Ounce suffer most, being almost destroyed in places, while Baldwin, Wagener, Rhode Island Greening and King follow in the order of severity of attack, the worst diseased first. Tallmon Sweet is said to be practically free from attack. Some of these varieties are unsuited to our climate while others are valuable varieties.

Treatment.—Prune out all diseased wood, cutting somewhat below the dead portions to insure the removal of all the infected part. Make all cuts neat and smooth, always cutting a branch off in such way as to leave no projecting stub. Collect and promptly burn all wood cut from trees. Avoid unnecessary wounding of trees by farm implements in cultivation or by ladders or shoes in harvesting. Treat all wounds to prevent access of fungous spores and to promote healing. This will mean smoothing off the surface of the wound and removing any dead or decaying wood or bark so that a clean-cut, sound edge is left for healing. Next wash the surface with a good antiseptic substance, such as a weak solution of corrosive sublimate, or Bordeaux mixture, or lime-sulphur mixture. This should be followed on larger wounds by some permanent covering such as pure thick paint without drier.

Since black rot attacks leaves and fruit, its control will also depend on care of these. Diseased fruits should not be allowed to accumulate on the ground. In off years as well as in bearing years the foliage should be protected by spraying with lime-sulphur, 1 1-2 gallons to 50 gallons of water, just before the blossoms open and just after the petals fall; and with 3-4-50 Bordeaux mixture three weeks later. Trunks, limbs and twigs should be coated as much as possible in the earlier applications; and a winter application of lime-sulphur, one gallon to ten gallons of water, will be of further advantage in protecting these parts.

EUROPEAN CANKER.

History.—As indicated by its name this disease obtained prominence in Europe long before it made its appearance in America. About the year 1900, this canker began to attract attention in New York and Nova Scotia, and since that time it has appeared more or less frequently in different parts of the United States as an apple disease.

Cause.—This canker is caused by a fungus quite different from that of the New York canker, known botanically as *Nectria ditissima*, Tul. (*Nectria coccinea* [Pers.] Fr.) This fungus attacks a wide range of trees and shrubs, including beech, oak, hazel, ash, hornbeam, ironwood, maple, linden, dogwood, magnolia, cherry, gooseberry and others; and it lives as a saprophyte on almost any kind of dead deciduous wood.

Distribution.—In America this fungus ranges from Canada southward, throughout the United States. As an apple disease it has gained most prominence in the apple regions of New York, New England, Eastern Canada and on the Pacific Coast. Recently a disease similar to, if not identical with this, has appeared in a serious form in North Carolina. The first report of this disease came from Lincoln County in the fall of 1909 and later it was reported from Sampson and Burke counties, indicating a wide distribution in the State.

Symptoms.—In all cases that have come to the notice of the writer a whitish or pinkish, weblike growth has appeared on some branches of the affected trees. This may or may not be connected with the cankers which develop upon the tree. Its habit of growth is somewhat like Hypochnose (See Bulletin 206 p. 90 of this Station), but the disease is quite a different one.

The canker of this disease may appear on either the trunk or larger branches of the trees, apparently never on the smaller twigs. At first



Fig. 2.—Fruiting bodies of the European Canker. Enlarged about twice.

the bark shrivels and turns grayish, assuming the appearance of being in a drying condition. This becomes most conspicuous in the late summer or in early fall. By spring the outer bark cracks and breaks away, more or less exposing the yellowish brown inner bark, which is covered rather sparingly with small pinkish pustules (Fig. 2), where the spores of the fungus are borne. These spore-bearing bodies average about one-twelfth of an inch in length, but may be either longer or shorter.

After the formation of spores the bark continues to crack deeper and fall away, leaving the wood exposed. The fungus lives in the inner

bark, in the cambium layer, and to a certain extent in the younger wood. Even at an early stage of the canker there may be a well defined line of separation between the healthy and diseased bark (Fig. 3). If the canker has not girdled the limb, the disease will not necessarily kill the branch attacked, but its growth is usually permanently arrested.

After the bark has fallen away from the original canker the fungus may persist and form a perennial canker, but usually the old canker

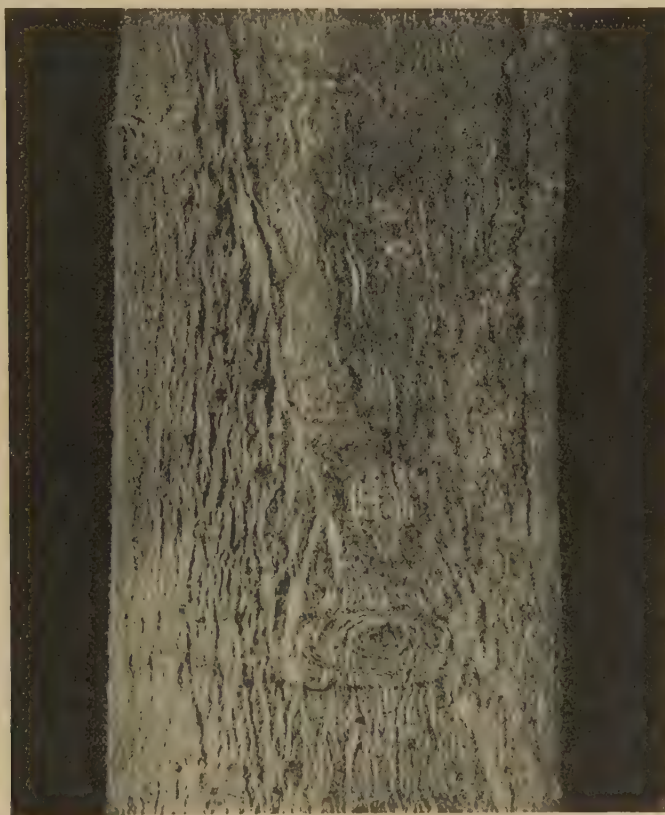


Fig. 3.—European Canker on apple branch, showing boundary of healthy and diseased areas.

merely becomes deeper and more gnarled by the growth of successive layers of wood and the attempt of the tree to heal the wound.

The crotch appears to be the favorite seat of first infection (Fig. 4), while later cankers appear farther up the branches. These spread rapidly over the tree and to new trees in the immediate vicinity. A tree with a crotch canker may have scarcely a healthy branch of any considerable size, and a single diseased tree may infect a dozen or more adjoining trees in a single season. It appears that from three to five years only are required for the total destruction of a young orchard.

Fungus.—The fungus which causes the European canker, like many other parasitic fungi, has two stages in its development, in each of which fruiting bodies and spores are produced which are very unlike each other. The first type of spore-bearing bodies to appear are the pink pustules mentioned above. These consist of a dense mat or cushion of fungous tissue upon which the almost colorless conidial spores are borne. Later in the season on the same cushion-like body there appears a small red flask shaped body known as the perithecium.

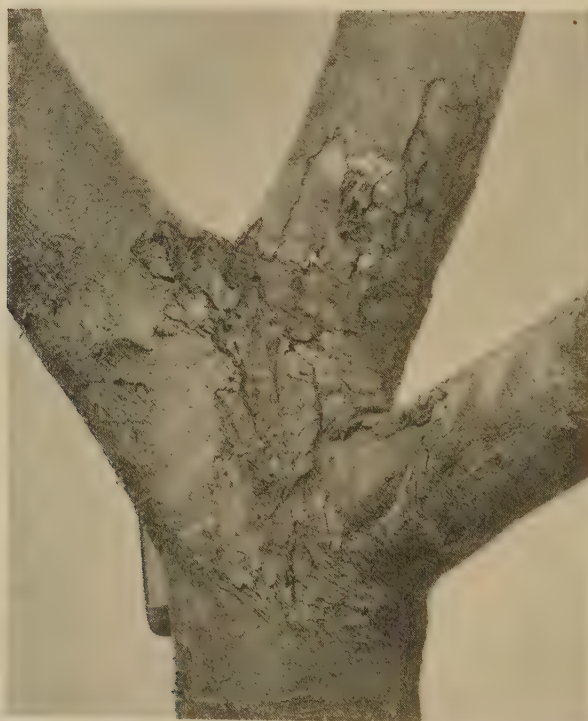


Fig. 4.—Large crotch canker of European Canker. Slightly reduced.

This is about one-twelfth inch in length, bright, almost scarlet red, with a distinct beak. Inside the perithecium are borne large numbers of spores in sacks, called asci.

So far we have found the conidial form of the fungus rather abundant, but the last named type has not been found so commonly. The conidial fruiting bodies of the European canker fungus are quite unlike those of any fungus related to it and agree well with those produced by the present fungus. While the conidia germinate readily and are easily cultivated, the spores produced by the ascus-bearing stage of the fungus do not lend themselves nearly so readily to study. Although this evidence all points to the presence in North Carolina of the European canker in a very virulent form, and while there is little room for

doubting the correctness of the determination of this disease, further study may show our form to be a distinct but closely related fungus.

Resistant Varieties.—So far as the writer knows there does not appear to be any considerable difference in the resistance of varieties to this disease, all of those exposed becoming infected and sooner or later succumbing to the attack.

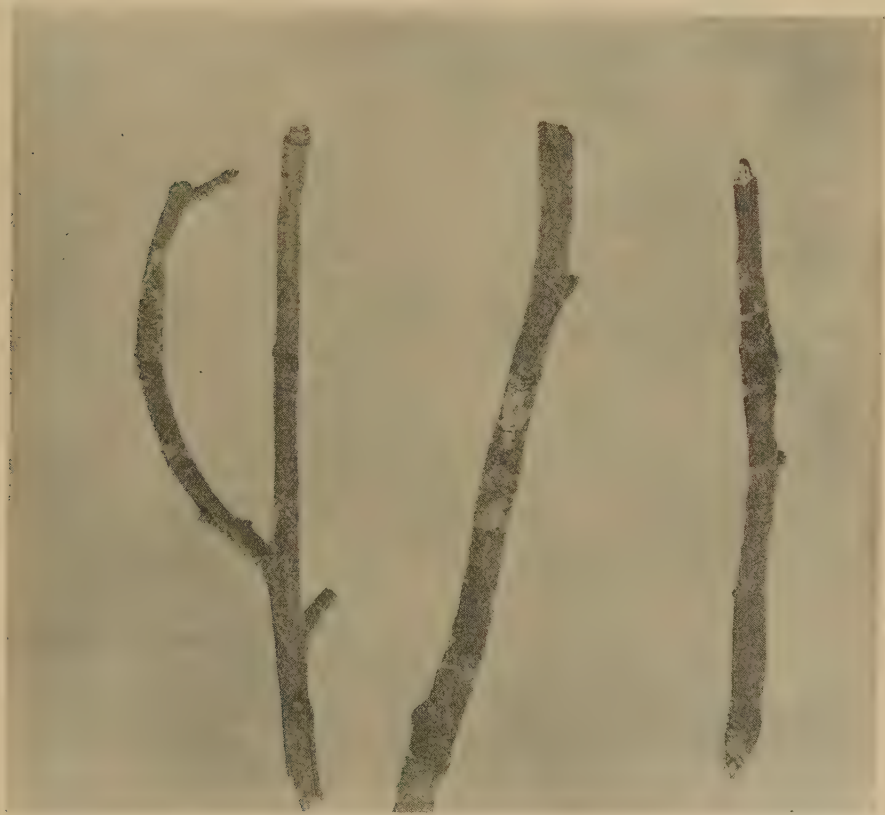


Fig. 5.—Thelephorose, showing fungous growth enveloping small branches. About natural size.

Treatment.—As the fungus which causes the European canker is supposed to be unable to enter the tree until the bark is first injured by some other agency, the freedom from this disease depends even more than in the case of the New York canker upon proper care of the orchard, in promptly removing all infective material, in avoiding wounding, and in protecting unavoidable wounds.

THELEPHOROSE.

History.—This disease first attracted attention in 1890, when the United States Department of Agriculture announced that apples in Texas and pears in Alabama were subject to its attacks. The first

report of the disease to reach this Station was sent from Lincoln County in February, 1911, when some orchards were said to be rather seriously affected. It has since been reported from Mecklenburg, Polk and Yancey counties.

Cause.—This disease is so named as the fungus which causes the disease was formerly placed in the genus *Thelephora*. It is now known



Fig. 6.—*Thelephorose*. Cross section of fungous mat, showing spongy structure and large cavities below. Highly magnified.

as *Septobasidium pedicellatum* (Schw.), Pat. This fungus is a near relative of the toadstools and punk knobs which are common about stumps and logs and on dead or living timber.

Symptoms.—It occurs on the twigs or trunks of the tree, usually at a dormant bud or at the base of a fruit spur or twig. The spots are from one-half inch to four or five inches long and vary in width according to the size of the branch, sometimes completely surrounding it

(Fig. 5). The fungus is grayish brown or smoky colored, with lighter margins. The spots in time become sunken and the bark and wood beneath is seen to be dead. The fungus growth is easily removed and is of a very spongy texture to the touch. Upon examination with the microscope the reason for this becomes very apparent. While the outer portion of the fungus is continuous and rather closely and compactly formed, a little way beneath the surface large cavities appear. These enlarge toward the affected branch so that a cross section of the fungus has the appearance of a flat roof supported by pillars (Fig. 6). This is the characteristic which gives the fungus its specific name, *pedicellatum*.

Distribution.—This fungus occurs throughout eastern North America, as well as in Cuba, in Ceylon, and in New Zealand, growing upon various deciduous trees such as apple, pear, oak, etc., and on the palmetto. With such a wide range of hosts the fungus does not necessarily depend upon the orchards for its distribution and so may appear in destructive abundance in any orchard which is not well cared for. It has been recorded on the apple from West Virginia and Georgia, in addition to the localities mentioned above.

Treatment.—Cut out all badly diseased twigs, or in case of occurrence on the trunk or larger limbs remove all dead wood, washing the wound thoroughly in a saturated solution of copperas and cover with grafting wax or some similar substance. The quantity of copperas used in making the solution should be sufficient to allow some undissolved crystals to remain in the vessel. With proper care this disease should not prove serious. Winter spraying alone of dormant trees with strong fungicides will doubtless prevent it from gaining a foothold in orchards.



Fig. 7.- Crown of dewberry and blackberry affected with Orange Rust (*Gymnosporium*).

RUSTS OF BLACKBERRIES, DEWBERRIES, AND RASPBERRIES.

By GUY WEST WILSON.

These three fruits all belong to the genus *Rubus* of the rose family (*Rosaceæ*); and as might be expected from their close relationship they harbor, to a great extent, the same fungous pests. Of these pests the rusts are not the least common or destructive. Of these we have three forms in North Carolina, two of which certainly and the third in all probability are closely related to the rusts (*Phragmidium* spp.) which occur on various other members of the rose family. These three rusts vary in importance as well as in appearance.

ORANGE RUST (*Gymnoconia interstitialis* [Schlecht] Lagerh).

This is the most common and most widely spread of the bramble rusts. First discovered in northeastern Asia almost a century ago, it is now known not only in Europe and Asia, but almost throughout the United States. It infests a large number of species of blackberries, dewberries and raspberries, both wild and cultivated, and often causes severe losses. In fact several cases have come under the writer's notice where berry growing had to be abandoned for a time due to its ravages. The mycelium, or the threads of the fungus, live from year to year in the plant and spread to all its parts so that, once infected, the disease persists until the host plant is killed.

In the host plant the fungus acts as a stimulus to growth frequently causing an excessive number of young canes to be produced (Fig. 7), which appear at first to be more vigorous than the normal healthy canes, while at the same time development is retarded beyond a certain point. The leaves are dwarfed, and rolled and lacking in their normal green color, while the canes do not develop and bear fruit as they should.

Even in the early spring before the buds are fully unfolded, the fungus is apparent to a close observer. The leaves, especially on the upper surfaces, are covered with small, bright yellowish, columnar, waxy, glandlike bodies which enlarge as the leaves expand. These are the pycnidia or spermogonia which are present in all rusts but are not usually so conspicuous as in the present instance.

A little later the familiar bright orange colored spots appear in which are borne millions of spores. These spots are irregular in form and often run into each other (Fig. 8). They frequently cover the greater part of the surface of the leaf and produce spores so abundantly that the shoes and clothing of a person walking among infected plants becomes covered with them. These spores spread the fungus from one plant to another.

Later in the season inconspicuous spore masses of another type are produced, in which the winter spores are borne. These spores, as well as the perennial mycelium, carry the fungus over to another season,

and like the more abundant early spores cause additional plants to become infected.

On account of the perennial nature of the fungus it is impossible to combat it except by digging and burning the infected plants. Care should be taken to prevent the spread of the disease among wild plants in the vicinity of plantations of berries as this furnishes a constant source of infection for healthy plants.

LATE RUST (*Kuehneola albida* [Kuhn] Magnus.)

As its name indicates this rust does not appear until late in the summer, usually after the fruit is matured. This rust is rather inconspicuous, producing small light yellow or whitish spots (sori) on the under



Fig. 8.—Blackberry leaf, showing orange colored spots of the fungus *Gymnoconia*.

side of the leaves. The light color of these sori has given rise to the appellation of white rust which is, however, scarcely a correct name as the fungus is usually a light yellow in color.

While widely distributed over North America and Europe this rust has not given much trouble, yet under favorable conditions a serious outbreak of the disease might occur. This rust is unknown on the raspberry and seems to be confined to the blackberry.

CANE RUST (*Uredo muellerii*, Schröt.).

This rust, also called the yellow late rust, occurs on wild and cultivated blackberries in eastern North America from New England southward. Although known in Europe for many years and first reported

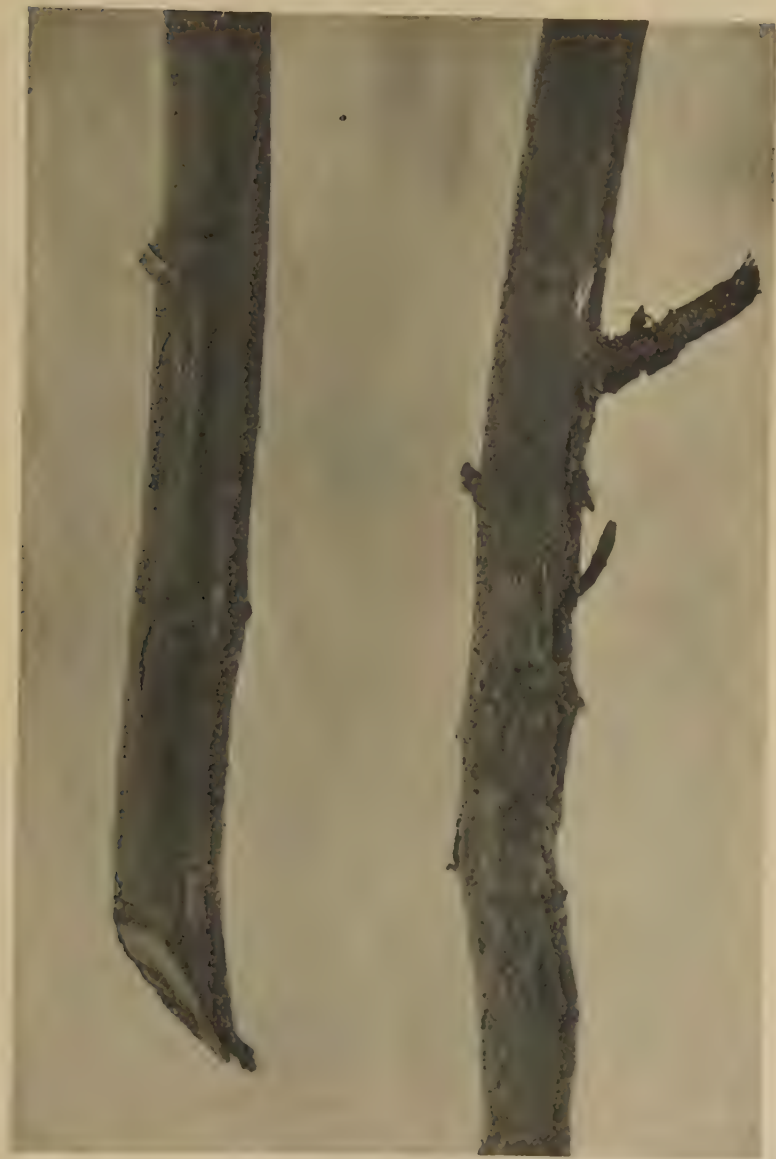


Fig. 9.—Blackberry canes, showing the Cane Rust (*Uredo muellerii*).

in this county in 1900¹ from New York it has not been looked upon as a serious pest, the statement of its American discoverers being generally accepted. They say "there is no cause for alarm. * * * It appears too late in the season to do much damage." Observations in

¹Stewart, Rolfs and Hall, N. Y. State Agr. Expt. Station, Bulletin 191, p. 306.

North Carolina extending over a number of years indicate that such a complacent view may be incorrect, at least in the more southern range of the species. Although no extensive examination of diseased plants has been made the fungus appears to be perennial. If this is true it may assume a very important role in the growth of certain varieties of blackberries in the South.

Just before, or about blooming time the rust makes its first appearance with us, first as a cane rust and later in the season as a leaf rust. This rust produces conspicuous spots on the canes from the ground up. These spots are often a third of an inch long and about half as wide, although they average a little smaller (Fig. 9). These sori are ac-



Fig. 10.--Sorus of *Uredo muellerii* on blackberry. Enlarged 20 times.

companied by tiny waxy pycnidia, which are very inconspicuous. Spores are produced in large numbers but not nearly so abundantly as in the case of the orange rust (Fig. 10).

Throughout the summer small rounded sori appear on the leaves which are also accompanied by pycnidia, and which resemble in certain ways the sori of the late rust (*Kuehneola*), but differ from them in several respects. The sori are bright yellow instead of almost colorless and usually appear on the upper side of the leaf more abundantly than

on the lower, while in the late rust the reverse is true. The rust is not abundant enough on the leaves to cause any serious damage.

Only the early stages in the life history of this rust are known. From the frequent association on the same plant of this rust and *Kuehneola* and the absence of known winter spores in this species it has been assumed that *Uredo muellerii* represents the first part of the life cycle and *Kuehneola albida* the later stages of the same rust. This has not been proven by experiment, the one never having been grown from the other, and until this is done this can be only an assumption.

This rust occurs from year to year on the same host plant, and its habit of producing sori throughout the entire length of the cane indicates that it is a perennial fungus. Its chief damage to the host would lie in a weakening of the canes with consequent lessened productivity. This can be largely overcome by proper pruning in the spring. While this rust is not nearly so serious as the orange rust it may prove to be a more serious disease than at first supposed.

INFECTION OF APPLE LEAVES BY CEDAR RUST.

By H. R. FULTON.

The Orange Rust or Cedar Rust of apple leaves and fruit is caused by one or the other of several species of *Gymnosporangium*, but mainly by *Gymnosporangium macrosp.* and it is to this species that the statements in this account relate. This fungus causes the swellings known as "cedar-apples" on the twigs of red cedars, and it is in these that the fungus lives over winter. In early spring the fungus forms large yellowish-brown spores (teliospores) in pustules in the cedar-apples. Warm rains from March into May may cause these spores to exude in gelatinous horns, and if sufficiently prolonged will give them a chance to germinate in these horns. On germination they at once form a short threadlike growth, known as the promycelium, which in turn quickly produces a certain number of smaller, more delicate spores that are capable of infecting the apple immediately if they get the chance. From the first swelling of the gelatinous horns to the formation of the infection spores about 24 hours of moisture are required. These infection spores retain their vitality for only a short period, which varies with their surroundings. Not all the teliospores germinate during any one wet period, but do so at several times during the spring whenever moisture conditions favor.

Apples can be infected only when viable infection spores reach them from the cedar-apples, and this depends intimately upon weather conditions during the spring months; furthermore, weather conditions must be favorable for the germination of the infection spores after reaching apple leaves or fruit. Along with the presence of infection spores and favorableness of weather conditions, susceptibility of the host is a third factor concerned in infection.

Cedar-apples on red cedars are very constant in occurrence each season. But apples in the eastern United States are severely attacked by this fungus at irregular intervals of years. Ordinary applications of fungicides have not given uniform success in controlling the disease. This study was undertaken to ascertain the importance of factors influencing infection with a view to explaining the irregularity in outbreaks and to finding a clue to a more successful spraying practice for it. Leaf infection only is here considered.

Varieties of apple differ much in their susceptibility to this disease, as may be readily observed in any mixed orchard that is attacked. In the spring of 1912, near Raleigh, N. C., observations show that Fallawater (Pound), Horse, Shooklev, Red June, and Rome Beauty varieties are much affected on foliage; that Hoover, Magnum Bonum, Red Limbertwig, and York Imperial are moderately affected; that Buckingham, Winesap, Stayman Winesap, Salome, Paragon, Williams, and Maiden Blush are slightly affected; and that Arkansas, Delicious, Jefferis, Mag-nate, Lawver and King David are not at all affected.

In the experimental tests, inoculations were made by spraying infection spores with an atomizer on the leaves, usually just about sunset.

Cedar-apples were placed in moist dishes twenty-four to forty-eight hours before to insure good infection spores. Inoculations were made almost daily from March 26 to May 7, under all sorts of weather conditions. They were made on Fallawater, Magnum Bonum, Salome, Winesap, Stayman Winesap, Arkansas, Lawver, Paragon, and one unknown variety of apple, and on two unknown varieties of crab-apple.

Weather conditions that prevailed during the test are indicated in the following table compiled from reports of the Raleigh Station of the United States Weather Bureau. Days with no rainfall are omitted.

Date.	Mean Temp.	Rainfall in Inches.	Percentage Sunshine.	Date.	Mean Temp.	Rainfall in Inches.	Percentage Sunshine.
March 22-----	56	.17	0	April 20-----	54	.17	11
23-----	38	.91	0	21-----	56	.09	0
24-----	48	.25	0	22-----	64	1.93	18
25-----	47	.08	78	23-----	60	.01	100
26-----	58	trace	9	26-----	62	trace	42
29-----	66	1.45	59	27-----	65	.02	27
April 1-----	64	.16	25	29-----	69	.75	39
2-----	68	trace	52	30-----	70	.01	74
7-----	58	.29	4	May 5-----	67	.19	36
10-----	64	trace	50	6-----	72	1.57	27
13-----	65	.02	10	7-----	74	.36	41
16-----	71	.06	36				
17-----	71	.23	23				
18-----	71	trace	67				

Infection resulted from certain of the trials made on Fallawater, Magnum Bonum, Salome, Winesap, Stayman Winesap, and Paragon, but not on the other varieties tested. For these there was considerable difference between the most susceptible variety, Fallawater, and the least susceptible, Paragon, both in the rate of development of the spots, and in the size ultimately attained, while there was not so great difference in the number of spots per leaf. It seemed that infection started on all susceptible varieties, but that growth of the fungus was inhibited in the most resistant ones before the spots had reached any considerable size.

The two periods during which artificial infections occurred were uniform for the varieties and centered about April 1 and April 21. Since Fallawater showed the effects most conspicuously, and since the other affected varieties did not present any exceptional conditions, the data for it alone will be given. The first infection was noted April 15 on leaves inoculated March 28, and the spots were then 1-12 inch across and showed spermatogonia. At the same time infections of March 30 and more abundantly of April 1 appeared as smaller yellowish dots. Twenty-four twigs developed this early infection. Attempts to inoculate had been made every day from March 26 to April 2, with the exception of March 31. While there was no rain March 30, the day was

humid and still. That infections did not occur on the other four days when similar infective material was placed on leaves of similar development, suggests the sensitiveness of the infection spores to external conditions.

On March 26 the Fallawater flower cluster buds were opening, exposing the leaves about one-fourth inch beyond the bud scales. The flower buds proper were still fairly well covered by the unexpanded leaves. The leaf buds were swollen, occasionally showing slight green. By April 3 the flower buds proper were exposed but the petals were not showing between the sepals. The leaves were one-fourth to three-fourths inch long.

This early infection was practically confined to fruit spurs which produced a total of six or seven leaves, including the lowermost two or three small, bract-like leaves. Only two out of the twenty-four twigs showed infection beyond the third leaf from the bottom. The majority of the twigs had no infection on the first leaf. Infection was, therefore, typically on the second and third leaves rather than on others.

Why was it that during these inoculations the one lowermost (oldest) leaf escaped infection in the majority of cases, and several uppermost (youngest) leaves escaped constantly, although the development of the buds was such as to favor the lodging of infection spores on all? The reasonable answer seems to be that each leaf is most susceptible during a brief period only in its development, and that at younger and older stages it is less susceptible or entirely immune. The fact that some of the youngest leaves on these same twigs became infected three weeks later, and that none of the older leaves developed any of the later infection, further substantiates the point, as do other facts that will be brought out later.

In their later development the spots on the bract-like leaves seemed to form a thicker cushion than spots of equivalent age on normal foliage leaves.

The second period of artificial infection centered about April 21 and was first noticed as small spots on April 30. Natural infection occurred about the same time; the experimental twigs were not protected from this, and the exact determination of days was slightly complicated thereby. There was some infection on April 16 and 20, but it was small in amount, not nearly so much as on April 21, and will not be considered. Inoculation dates were April 15, 16, 17, 20, 21 and 24.

Fifteen Fallawater twigs became infected at this time artificially. None of these showed infection lower than the fourth leaf, in seven it began on the fourth leaf, and in the other eight on the fifth or sixth leaf. Typical infection involved all the leaves above these on the stem, although in five cases one or more topmost leaves escaped infection. However, three of such twigs were terminal shoots that were elongating and forming new leaves indefinitely. Maximum infection was typical about midway of the three or four leaves showing infection, the first and last affected leaves having distinctly fewer spots than those between.

On April 16 the petals had all fallen and the new shoots were a little more than one inch long and showed seven or eight leaves, the full

number except for those continuing indefinite growth. At this time the sixth leaf was about half full size, and this is the leaf that on the average seemed most susceptible during the next few days.

Natural infection was first noted on Fallawater on April 30, when minute infection spots appeared generally on certain leaves on most of its twigs. In a few days similar infection could be detected on other varieties. From comparisons with the series of artificial inoculations it is certain that this infection dates from the showery period of April 20-22. No other natural infection corresponding to other rainy periods was detected.

The condition of the teleutospores in the cedar-apple horns is interesting in this connection. On March 26 the horns barely protruded, and only about 1 per cent of the teleutospores had germinated. The hard rain of March 29, confined to the night with clearing in the forenoon, did not greatly alter their condition. By April 12, 10 per cent of the teleutospores had germinated; by April 19, 35 per cent; by April 25, 75 per cent; by May 2, 90 per cent, and by May 7, practically all. The period of greatest germination, April 19 to 25, includes that of the natural infection in question.

Examination of a large number of twigs of Fallawater naturally infected during this period shows that the lowermost affected leaf was usually the fifth from the bottom, and never lower than the third nor higher than the seventh; that the uppermost affected leaf was usually the eighth; that the sixth and seventh showed most abundant infection, with gradation in degree up and down, three or four leaves in all out of eight or nine on the typical twig having any infection. Frequently the spots on the lowermost infected leaf were quite small, as on more resistant varieties.

These data agree with those from twigs artificially infected at the same period. All go to show that the lowermost and oldest leaves on the twigs were not infected, although equally exposed with others to infection spores and to favoring moisture. These must have passed with increasing age of the individual leaf from a condition of susceptibility into one of non-susceptibility, and by April 22, 1912, almost half the leaves on this Fallawater tree had reached such a condition of immunity. Passing further outward along the twig are the zones of partial susceptibility, of maximum susceptibility, and again of partial susceptibility or of immunity apparently due to young condition. It may be that the escape of very young leaves is due in part to lessened chance for spores to lodge on them when unexpanded; but this does not seem from the facts to be the whole explanation.

It is seen that for the season of 1912 teleutospores were capable of germination for about six weeks; that they formed infection spores abundantly only when there was continuous wet weather for about two days; that infection of apple leaves was produced by these spores only when the wet weather was more prolonged, giving a chance for germination after being distributed; that only a certain proportion of apple leaves on any twig were infected at any one time; that the susceptibility of the leaves was determined by their age; and that at least some leaves were susceptible in some degree from the bursting of the

buds until about two weeks after the falling of the petals. All of these facts accord essentially with those obtained by the writer during the spring of 1911 in the vicinity of State College, Pennsylvania.

To give adequate and sure protection it would seem that spraying for this disease should be begun just after the leaves emerge from the buds, and should be repeated as often as necessary to keep the expanding leaf surfaces protected. The failure of ordinary spraying to protect has probably been due to beginning too late or to too infrequent applications. Infection really occurs ten days before the spots become apparent. A tentative schedule, recommended for trial, would include applications (1) just after the leaves are out of the bud, (2) just before the blossoms open, (3) just after the petals fall, and (4) ten days later. It will be noted that the last three of these applications coincide with those for full scab treatment. Only decidedly susceptible varieties need be thus protected. The danger period is only during wet weather; but to protect the spraying must be before, not after such a period. If weather conditions could be foretold with exactness one or two sprayings could be made to do the work. When all is said, the inherent difficulties in the spraying method of control strongly emphasize the importance of removing from the vicinity of the orchard the red cedar trees that are the source of contagion. Usually bad infection comes from cedars very close at hand that it will be possible to get rid of. The farther away the cedar tree is, the less chance is there of spores from it reaching any particular apple tree. With coöperative interest in cedar tree removal, it is not probable that spraying for this disease would be often necessary.

V—STUDIES IN SOIL BACTERIOLOGY¹

NITRIFYING AND AMMONIFYING POWERS OF NORTH CAROLINA SOILS.

By

F. L. STEVENS AND W. A. WITHERS,

ASSISTED BY

P. L. GAINNEY AND T. B. STANSEL.

The strikingly low nitrifying power noted in preliminary bacteriological studies of certain soils² emphasized the importance of obtaining more extensive and accurate knowledge concerning this function. To that end plans were drawn for an examination of samples of the leading soil types, to be taken in such localities as to give as adequate a representation of the soils of this State as was practicable. The samples were taken from areas already covered by the United States Soil Survey and were all examined by George M. MacNider, of the North Carolina Department of Agriculture, formerly of the United States Soil Survey, who made definite determination of the type in hand in each instance. We very gratefully acknowledge our indebtedness to Mr. MacNider for this kindness.

In each instance, with three exceptions, the soil samples were taken in pairs for purposes of comparison; one sample of the pair from a very rich field of the type in question, the other from a very poor field of identically the same type of soil, preferably located in an adjacent field; in several instances from a poor spot in the same field from which the rich sample came. The samples were collected in tin pails with tightly fitting tops, were sent to the laboratory by express and the determinations were made shortly after their receipt, with the exception of determinations of Nitrifying Efficiency (N. E.), which were in some instances delayed.

The following directions were given to each collector in order to eliminate as far as possible any error from contamination:

"Pull all vegetation from the place to be sampled.

"At one stroke with a shovel, remove one inch of the surface from an area one to two square feet.

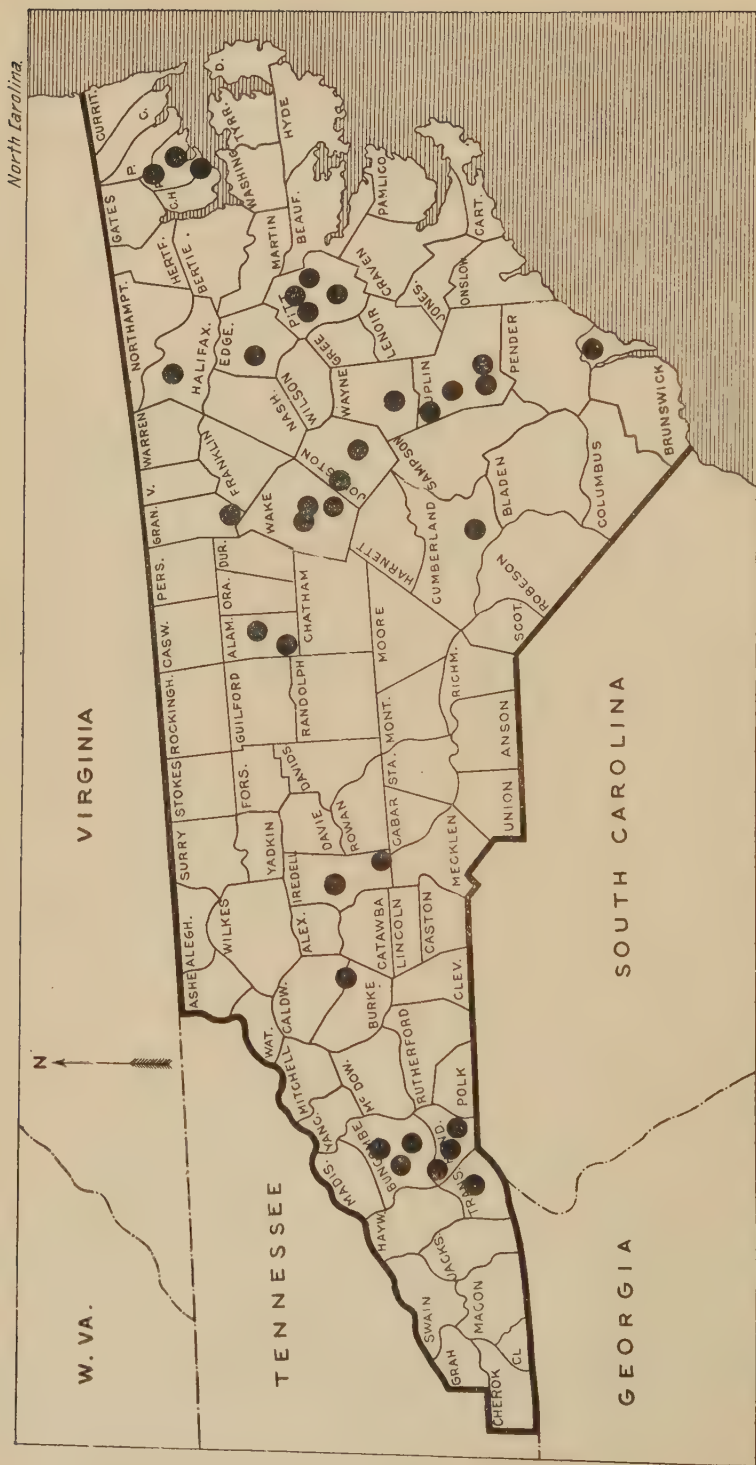
"Remove about $\frac{1}{4}$ inch more with the sterile trowel provided in the pail.

"Fill the pail with soil so exposed, free from stones, sticks, roots, etc., using the sterile trowel.

"Use every precaution to avoid allowing dust or organisms from any source other than the soil to fall into the pail."

¹Articles I, II, III, and IV appeared in *Centralblatt für Bakteriologie*, Ab. II, Bd. 23, 25, and 27.

²*Science* N. S. 29, 743, 506, Mch. 1909.



MAP SHOWING THE LOCATION OF THE SOILS SAMPLED.

Notes in the following blank form also elicited desired information:

Yielding power in bushels of shelled corn per acre.....
 Yielding power in pounds of seed cotton per acre.....
 Yielding power, regarding any other crop, per acre.....
 Crops grown 1909.....Fertilizer or manure used in 1909.....
 Crops grown 1908.....Fertilizer or manure used in 1908.....
 Crops grown 1907.....Fertilizer or manure used in 1907.....

In the study of nitrifying power the following determinations were made:

N. E.: Nitrifying Efficiency.

N. I. P.: Nitrification Inoculating Power.

Also for purposes of comparison of methods the N. I. P. was determined in solution.

Determinations of ammonification were made as follows:

A. E.: Ammonification Efficiency.

A. I. P.: Ammonification Inoculating Power.

A. I. P. in solution.

These terms and methods of making the determinations were discussed in full in a recent article.¹

If it is desired to convert our coefficients for nitrification to parts of nitrate nitrogen per million parts of soil this may be done by multiplying our coefficient by six.

The soil survey was begun March 4, 1909, and concluded January, 1911. In all seventy-nine soils were examined, 37 of these being poor and unproductive, while the productivity of three which had never been cultivated was unknown.

The soils came from twenty counties in North Carolina as follows: Alamance 6, Buncombe 6, Caldwell 2, Chowan 4, Craven 2, Cumberland 2, Duplin 8, Edgecombe 2, Granville 2, Henderson 6, Hertford 2, Iredell 6, Johnston 4, New Hanover 4, Pasquotank 1, Perquimans 4, Pitt 8, Transylvania 2, Wake 6, Wayne 2. The location of the soils sampled is shown on the accompanying map.

The soil types represented were as follows: (1) Cecil clay 4, (2) Cecil sandy loam 8, (3) Conowingo sandy loam 2, (4) Iredell clay loam 4, (5) Meadow 2, (6) Norfolk coarse sandy loam 2, (7) Norfolk fine sand 3, (8) Norfolk fine sandy loam 4, (9) Norfolk sand 6, (10) Norfolk sandy loam 11, (11) Norfolk very fine sandy loam 2, (12) Orangeburg fine sandy loam 2, (13) Poccosin 1, (14), Porter's clay 2, (15) Porter's loam 2, (16) Porter's sandy loam 6, (17) Portsmouth fine sandy loam 5, (18) Portsmouth loam 1, (19) Portsmouth sand 2, (20) Portsmouth sandy loam 2, (21) Portsmouth very fine sandy loam 2, (22) Savannah 1, (23) swamps 1, (24) Toxaway loam 2, (25) Toxaway sandy loam 2.

In all 679 factors were determined as follows: N. I. P. in soil, 79; N. I. P. in solution, 79—1909; N. I. P. in solution, 57—1910; A. E., 79; A. I. P. in soil, 73; A. I. P. in solution, 71; N. C., 47.

This involved a total of approximately 1796 flasks of soil, each incubated separately, and in all required the following chemical analyses:

¹Stevens and Withers, III Soil Bacteriology, Centralblatt für Bakteriologie, B. 25, S. 64.

N. E., 548; N. I. P. in soil, 272; N. I. P. in solution, 272; A. E., 316; A. I. P. in soil, 146; A. I. P. in solution, 142; N. C., 100, or a total of 1,584 chemical determinations, viz.: Nitrates, 592; nitrites, 592; ammonia, 604; nitrates and nitrites, 1,796.

The results in their entirety are presented in the table accompanying this article. The original plan provided for the determination of all the factors in each collection of 1909, but in testing the method¹ for nitrites and nitrates it was found to be less delicate than desired. It was thought best, therefore, to set aside all the zeros for nitrites and nitrates for the 1909 samples. During 1910 samples were again taken from the same localities and determinations of the N. E., N. I. P. in soil and N. I. P. in solution made on these samples.

In 1910 we used a modification of the diphenylamine method by Withers and Ray² which the authors found to show as little as one part of nitrate and nitrite nitrogen in thirty-five millions of water, which is equivalent to about 0.3 pounds in an acre of soil. When nitrates or nitrites were indicated by the method the amounts were determined quantitatively—nitrites by the Griess³ method and nitrates by the phenol disulphonic acid⁴ method or the Tiemann-Schulze⁵ method.

NITRIFICATION.

COMPARISON OF METHODS.

TABLE I.—Showing comparison by different methods, calculated to per cent.

	N. E. with N. I. P.			N. E. with N. I. P. in Solu.			N. I. P. in Soil with N. I. P. in Solu.		
	Both Methods Give a Test.	Only One Method Gives a Test.	Total.	Both Methods Give a Test.	Only One Method Gives a Test.	Total.	Both Methods Give a Test.	Only One Method Gives a Test.	Total.
N. E. Greater	5.3	0.0	5.3	33.3	17.5	50.8			
N. I. P. Greater	49.1	43.8	92.9				64.3	30.3	94.6
N. I. P. in Solu. Greater				0.0	35.1	35.1	3.6	1.8	5.4
Total	54.4	43.8	98.2	33.3	52.6	85.9	67.9	32.1	100.0
Both methods give same result.			0.0	1.8		1.8			
Both methods give zero.			1.8			12.3			0
			100.0			100.0			100.0

¹Treadwell, Vol. I (1904), p. 340.

²Jour. Am. Chem. Soc., 33 (1911), 708.

³Bul. 31 Bureau of Soils, U. S. Dept. Agr., p. 41.

⁴Ibid., p. 39.

⁵Fresenius, Vol. I (1909), p. 582; Treadwell, Vol. II (1909), p. 360.

N. I. P. in soil with N. I. P. in solution.—By examining the above table No. 1 we see that of the soils tested 67.9 per cent showed N. I. P. in both soil and solution, 30.3 per cent showed N. I. P. only in soil and 1.8 per cent showed N. I. P. only in solution. The N. I. P. in soil was greater than in solution in 94.6 per cent of the samples and less in 5.4 per cent of the samples. It is evident from these results that the changes which take place in solution can not be accepted as an index to the changes which take place in the soil.

N. E. with N. I. P. in solution.—Of the soils tested 35.1 per cent showed both N. E. and N. I. P. in solution, 17.5 per cent showed only N. E., 35.1 per cent showed only N. I. P. in solution, and 12.3 per cent did not show nitrification by either method. The N. E. was greater than N. I. P. in solution in 50.8 per cent of the soils, was less in 35.1 per cent of the soils and was equal in 1.8 per cent of the soils in which there was nitrification by both methods, and in 12.3 per cent of the soils in which there was no nitrification by either method. It is evident from these results that the changes which take place in solution cannot be accepted as an index to the changes which take place in the soil.

N. E. with N. I. P.—Of the soils tested 54.4 per cent showed both N. E. and N. I. P., 43.8 per cent showed only N. I. P., and 1.8 per cent showed no nitrification by either method. N. E. is greater than N. I. P. in 5.3 per cent of the soils, is less in 92.9 per cent of the soils and is equal in 1.8 per cent of the soils in which there is no nitrification by either method.

General.—Every soil showed some nitrification by one or other of the methods, thus proving that in every soil there were living nitrifying organisms. Every method in one or more instances failed to show nitrification, thus proving that no method which we used afforded satisfactory conditions for the activities of the complexes in all the soils, one method being better suited to one complex, another to another complex, and that the findings by one method could not be taken as indicating what would be the findings by another method.

N. I. P. in solution was unsatisfactory in that the coefficients had a very narrow range and were all small. N. I. P. was unsatisfactory in that its coefficients were all very large, but satisfactory to the extent that all soils but one gave positive results. N. E. was unsatisfactory in that so many of the coefficients were zero or less, but there is in its favor that fact that the soil is used in its natural state without sterilization, and that as a rule the coefficients are not excessively large.

The fact that 42.6 per cent of the soils failed to show nitrification by the N. E. method when the conditions of temperature, moisture, etc., were arranged to be much more favorable to the activity of the nitrifying organisms, than under ordinary field conditions, suggests that the plant is not so dependent upon nitrates for its nitrogen as is generally supposed.

Variation in Nitrification at different periods.—Some of the soils which we used during 1909 were again sampled during 1910, the samples being taken from the same fields and by the same sampler. Some of these results are given in table 2.

TABLE II.—Showing a variation from year to year.

	N. E.			N. I. P.	
	1909.	1910.		1909.	1910.
No. 5.....	5.5	6.5	No. 5.....	4.7	74.1
No. 35.....	29.7	—10.6	No. 35.....	5.2	87.7
No. 29.....	16.1	0.0	No. 42.....	6.0	50.6
No. 31.....	39.5	36.1	No. 57.....	30.5	73.6
No. 47.....	13.5	0.0	No. 61.....	35.9	74.6
No. 49.....	50.6	—0.7	No. 65.....	60.2	85.3
No. 81.....	22.4	14.8	No. 66.....	4.5	46.0
			No. 67.....	65.8	4.3
Average.....	25.6	6.6	No. 69.....	30.7	0.0
			No. 75.....	35.1	6.2
			No. 77.....	11.6	27.5
			No. 78.....	3.3	3.9
			No. 79.....	62.6	29.2
			No. 80.....	43.1	82.6
			Average.....	28.5	46.1

These results given in table 2 show a great difference between the results for 1909 and 1910 in both N. E. and N. I. P. Strange to say the average of the N. E. decreased from 1909 to 1910 and of N. I. P. increased. Except in two cases the N. E. and N. I. P. were made on samples from different fields. In some cases soils which gave good nitrification one year showed none the following year.

CORRELATION BETWEEN FERTILITY AND NITRIFICATION.

The following table shows the relation between fertility and nitrification in soils as determined by the different methods.

Percentages of the pairs of good and poor soils nitrifying by different methods.

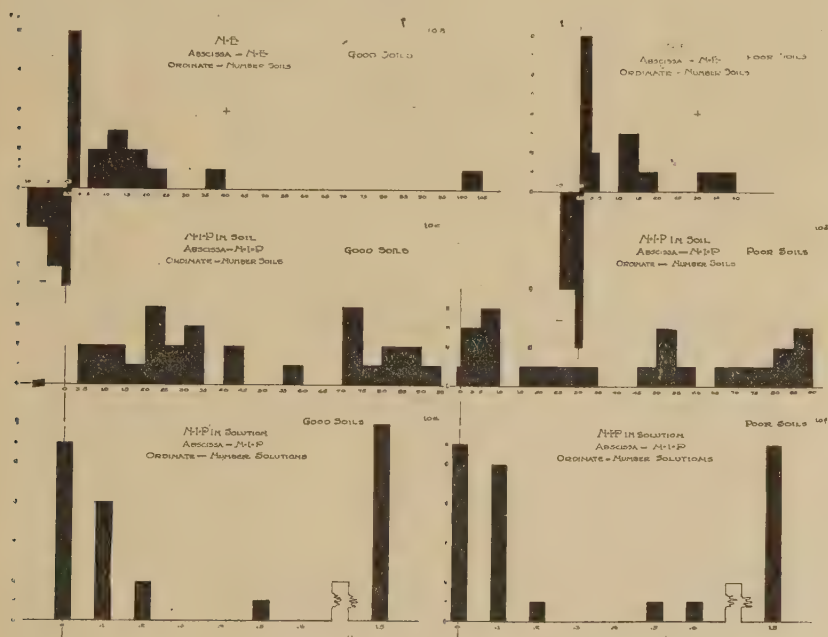
TABLE III.—Comparing nitrification by different methods.

	N. E.			N. I. P.			N. I. P. in Solu.			Average.		
	Both Ni-trify.	Only One Ni-trifies.	Total.	Both Ni-trify.	Only One Ni-trifies.	Total.	Both Ni-trify.	Only One Ni-trifies.	Total.	Both Ni-trify.	Only One Ni-trifies.	Total.
Greater nitrification by:												
Good soils.....	29.7	14.8	44.5	65.4	3.8	69.2	3.8	3.9	7.7	33.0	7.5	40.5
Poor soils.....	14.8	11.1	25.9	30.8	.0	30.8	3.8	.0	3.8	16.4	3.7	20.1
Total.....	44.5	25.9	70.4	96.2	3.8	100.0	7.6	3.9	11.5	49.4	11.2	60.6
Good and poor soils equal in nitrification.			.0			.0	57.7		57.7	19.2		19.2
Neither nitrifies.....			29.6			.0			30.8			20.2
			100.0			100.0			100.0	68.6		100.0

TABLE IV.—Showing summary of results by different methods.

	N. E.	N. I. P.	N. I. P. in Solu.
Maximum coefficient.....	105.1	89.9	1.5
Average for good soils.....	8.7	44.7	0.6
Average for poor soils.....	5.0	34.8	0.6
Average for all soils tested.....	6.8	39.8	0.6

The results by different methods for good soils and for poor soils are shown graphically by the following cuts:



N. I. P. in Solution and Fertility.—N. I. P. in solution shows the least correlation between fertility and nitrification, the good and the poor soil showing the same nitrification in 88.5 per cent of the pairs. The good soil gave greater nitrification than the poor in 7.7 per cent of the pairs and less in the case of 3.8 per cent of the pairs. The average for the good was the same as for the poor and the maximum was only 1.5 per cent.

N. I. P. and Fertility.—In the case of N. I. P., every soil showed nitrification except one poor soil. The good soil gave better nitrification than the poor in 69.2 per cent of the pairs, and less in 30.8 per cent. of the pairs, an excess in favor of the good in 38.4 per cent.

In Table V the difference of N. I. P. in favor of the good soils is strikingly shown:

TABLE V.

Type.	County.	N. I. P.	
		Good soil.	Poor soil
Cecil clay	Iredell.....	41.1	4.5
do.....	Alamance.....	78.7	5.4
Cecil sandy loam	Granville.....	85.3	46.0
do.....	Iredell.....	27.5	3.9
Conowingo sandy loam.....	Caldwell.....	80.7	30.0
Norfolk coarse sandy loam.....	Wake.....	10.7	5.8
Norfolk fine sand.....	Duplin.....	74.1	23.8
Norfolk sand	Wayne.....	23.2	0.9
Norfolk sand	Cumberland.....	4.3	0.0
Norfolk sandy loam	Johnston.....	6.2	0.9
Porter's sandy loam	Buncombe.....	30.4	5.0
do.....	Henderson.....	40.3	6.4
Portsmouth fine sandy loam.....	Perquimans.....	74.6	1.3
Portsmouth sand	Duplin.....	87.7	5.5
Toxaway sandy loam	Henderson.....	32.7	17.5
Average.....		46.5	10.5

On the other hand in Table VI the difference of N. I. P. in favor of the poor soils is more strikingly shown:

TABLE VI.

Type.	County.	N. I. P.	
		Good soil.	Poor soil.
Cecil sandy loam	Alamance.....	29.2	82.6
Meadow.....	Wake.....	18.7	87.5
Norfolk fine sandy loam.....	Pitt.....	22.9	76.0
Norfolk very fine sandy loam.....	do.....	11.3	28.7
Orangeburg fine sandy loam.....	Duplin.....	3.5	86.7
Portsmouth fine sandy loam.....	Chowan.....	23.2	80.5
Toxaway loam.....	Transylvania.....	20.4	52.8
Average.....		18.5	70.7

The average N. I. P. for all the good soils was 44.7 per cent, of the poor soils 34.8 per cent and of all soils 39.8 per cent. The excess of the average of the good over the poor soils was 9.9 per cent or 24.9 per cent of the average. This method is good in that it usually shows nitrification. It is objectionable in that the average (39.8) represents the production of nitrate nitrogen equivalent to the amount of 955.2 pounds to the acre for a month or 1965.6 for three months, which is

greatly in excess of the possible amount in the field under ordinary agricultural conditions.

N. E. and Fertility.—The N. E. would probably be regarded popularly as the factor of most significance since it is at least an approximate measure of the power of the soil to furnish nitrate nitrogen to the plants that may grow upon it. How important this factor really is is not yet accurately known. It may be very important. In some instances it may be of no significance.

It will be noted that seven rich soils showed N. E. ranging from 12.6 to 105.1 with an average of 32.3. These soils had an average corn yield of 36.4 bushels an acre. On the other hand eleven rich soils showed N. E. zero or less than zero and had an average corn yield of 35.5 bushels an acre. *In other words, the rich soils with an N. E. of 32.3 had about the same corn producing power as rich soils which showed no N. E.*

In Table VII the good soils exceeded the poor soils in nitrification.

TABLE VII.

Type.	County.	N. E.	
		Good soil.	Poor soil.
Cecil clay.....	Iredell.....	2.0	1.0
do.....	Alamance.....	36.1	11.7
Cecil sandy loam.....	Granville.....	2.2	0.1
do.....	Alamance.....	2.2	1.3
Conowingo sandy loam.....	Caldwell.....	105.1	0.1
Norfolk fine sand.....	Duplin.....	6.5	0.5
Norfolk sandy loam.....	Johnston.....	12.6	0.0
Porter's loam.....	Buncombe.....	21.1	-0.8
Porter's sandy loam.....	do.....	14.8	4.9
Portsmouth fine sandy loam.....	Perquimans.....	9.9	0.0
Toxaway sandy loam.....	Henderson.....	17.1	10.2
Average.....		20.9	2.7

On the other hand, in table 8 the good soils showed less nitrification than the poor soil:

TABLE VIII.

Type.	County.	N. E.	
		Good soil.	Poor soil.
Iredell clay loam.....	Iredell.....	19.2	34.2
Meadow.....	Wake.....	2.2	13.3
Norfolk sand.....	Hertford.....	1.8	17.3
Orangeburg fine sandy loam.....	Duplin.....	0.0	3.5
Portsmouth very fine sandy loam.....	Chowan.....	-0.7	38.8
Average.....		4.5	21.4

Considering all the soils examined *the good soils gave better N. E. than the poor soils in 44.5 per cent of the pairs and less in 25.9 per cent of the pairs*, an excess in favor of the good soil of 18.5 per cent. *In 29.6 per cent of the pairs, neither the good nor the poor soil showed any nitrification.* Of the pairs in which only one showed nitrification, it was the good soil in 14.8 per cent of the pairs and the poor soil in 11.1 per cent of the pairs.

The average N. E. for all the soils was 6.8. For the good soils N. E. averaged 8.7 and for the poor soils 5.0, an excess of 3.7, or 55.1 per cent of the average N. E. in favor of the good soils.

That our zeros are not absolute zeros is to be expected. In the determination of nitrites and nitrates in this paper we have not considered coefficients less than 0.1. This would correspond to nitrates and nitrites equivalent to 2.4 pounds of nitrogen found in an acre in one month, or 7.2 pounds per acre (approximately 7.2 kilograms per hektare) in three months. Crops require much more nitrogen than this, wheat 20 bu. per acre removes 35 lbs.; corn 65 bu. per acre, 75 lbs.; potatoes, 150 bu. per acre, 40 lbs. Oats, 30 bu. per acre, 50 lbs. Barley, 40 bu. per acre, 40 lbs.¹

It therefore appears that the soils which we record as of no N. E. are incapable of producing sufficient nitrate nitrogen to feed such crops, particularly as all the nitrate nitrogen in the soil can not in any case be available for the plant.

The soils recorded as having N. E. less than .4 (equals 28.8 lbs. of nitrogen per acre during three months) are also incapable of supplying enough nitrate nitrogen to the soil for the crop.

On the other hand some of the soils of good N. E. both here reported and previously reported have ample power to supply an abundance of nitrate nitrogen. For example soil No. 39 with N. E. 105.1 would produce during three months 7,567 lbs. of nitrate nitrogen per acre—an amount so large as to be entirely beyond conception in practice.

A question of serious practical importance, therefore, is whether the plants require nitrate nitrogen to supply their needs for nitrogen or whether some other forms of nitrogen will serve equally well.

The fact that so large a proportion as 42.6 per cent of the soils tested by us showed no N. E. is a condition not usually expected in arable soils.

Scrutiny of the comparison of N. E. with N. I. P. in soil and in solution shows that these factors do not run parallel, a fact that was postulated in our earlier article.²

The N. I. P. and the N. E. must be regarded as separate functions of the soil which must be separately measured.

In general the N. I. P. was higher in the good than in the poor soils. The average was 44.7 per cent for the good soils and 34.8 for the poor soils. None of those which showed N. E. failed to show N. I. P. in soil and 17.5 per cent of those which showed N. E. failed to show N. I. P. in solution. Forty-three and eight-tenths per cent of those with

¹Snyder's Soils and Fertilizers, p. 129.

²Stevens and Withers, III Soil Bacteriology, Cent. f. Bak. II, Abt. Bd. 25, p. 64.

N. I. P. failed to show N. E. and 30.8 per cent of those which showed N. I. P. failed to show N. I. P. in solution. Thirty-five and one-tenth per cent of those with N. I. P. in solution failed to show N. E. and 1.8 per cent of those which showed N. I. P. in solution failed to show N. I. P. in soil. The variations shown between N. I. P. in soil and N. I. P. in solution and N. E. all go to show that a given complex of soil organisms will give different records in different modes of test; soil favors some complexes, solution favors others; one soil may favor one bacterial complex more than it favors another complex. The results strongly support the use of soils rather than solutions for soil study.

It is peculiar that the N. I. P. in soil should so often (92.9 per cent of the cases) exceed the N. E., though in only 35.1 per cent does the N. I. P. in solution exceed the N. E. This would indicate that the standard soil used is superior to most of the samples examined as a medium for the growth of the nitrifying complexes used and that soil is superior to solution in this respect.

That nearly all soils showed N. I. P. in soil indicates that even though the soils did not show N. E. the organisms necessary to nitrification were present and that the responsibility for low N. E. rests rather with the soil itself than with any deficiency in its bacterial flora.

AMMONIFICATION.

Regarding ammonification it is seen that considering all the samples the A. E. ranges from .03 to 25.46 with the most of the samples giving an A. E. of between 5 and 20. With the poor soils the A. E. was mainly from 5 to 20, and with the good soils it was the same. In other words there is no apparent correlation between fertility and A. E.

Tabulating the soils of low A. E. for comparison with those of high A. E. the following is obtained:

Of 11 soils of A. E. 5, 2, or 2.6 per cent of the whole were poor.

Of 11 soils of A. E. 5, 9, or 11.8 per cent of the whole were good.

Of 28 soils of A. E. 15, 13, or 17.0 per cent of the whole were poor.

Of 28 soils of A. E. 15, 11, or 14.4 per cent of the whole were good.

The detailed statement is shown in the following table.

TABLE IX.

A. E.	Number.			Percentage.		
	Good.	Poor.	Total.	Good.	Poor.	Total.
25 per cent	1	0	1	1.3	0.0	1.3
20-25 per cent	1	4	5	1.3	5.3	6.6
15-20 per cent	9	9	18	11.8	11.9	23.7
10-15 per cent	9	6	15	11.9	7.8	19.7
5-10 per cent	10	16	26	13.2	21.0	34.2
0- 5 per cent	9	2	11	11.8	2.7	14.5
Total.....	39	37	76	51.3	48.7	100.0

A. E.	Number.			Percentage.		
	Good.	Poor.	Total.	Good.	Poor.	Total.
25 per cent +-----	1	0	1	1.3	0.0	1.3
20 per cent +-----	2	4	6	2.6	5.3	7.9
15 per cent +-----	11	13	24	14.5	17.1	31.6
10 per cent +-----	20	19	39	26.3	25.0	55.3
5 per cent +-----	30	35	65	39.5	46.0	85.5
1 per cent +-----	36	37	73	47.4	48.7	96.1
1 per cent -----	3	0	3	3.9	0.0	3.9
Total.....	89	37	126			100.0

Deficiency in A. E. is rare in these soils, 3.8 per cent only, and even where the soils are low in A. E. the fertility is not markedly affected, nor is there any correlation of high fertility with high A. E.

In general the A. I. P. in soil did not differ strikingly from the A. E. and practically the same conclusions would be drawn from examination of either set of results, though ammonifications were generally somewhat higher in A. I. P. than in A. E. tests.

A summary of the results is shown in the cuts on page 79.

GENERAL DISCUSSION.

It is clearly evident that the soils examined which included enough samples to be quite representative in this State showed a remarkably low nitrifying power as compared with soils examined and reported by others. The significance of this low nitrification as regards fertility is not known. It has long been believed that nitrate nitrogen is the form of nitrogen most acceptable to plants and in many text books it is even stated that the nitrate is practically the only form in which nitrogen is utilized by the plant.

These views are illustrated in the following quotations from standard works:

"Taking the effectiveness of nitrate soda as 100, that of sulphate of ammonia was 90."¹

"The nitrates are the chief source of the nitrogen supply of green plants."²

"* * * the nitrifying bacteria then oxidizing the ammonia supplying the plant with nitrates according to its requirements."³

"The average relative availability of Ammonium Sulphate was 69.7 on all crops for the ten-year period 1898-1907 (taking that of sodium nitrate as 100)."⁴

"In experiments carried on for twenty-five years to determine the relative effect of different forms of nitrogen, including nitrate of soda

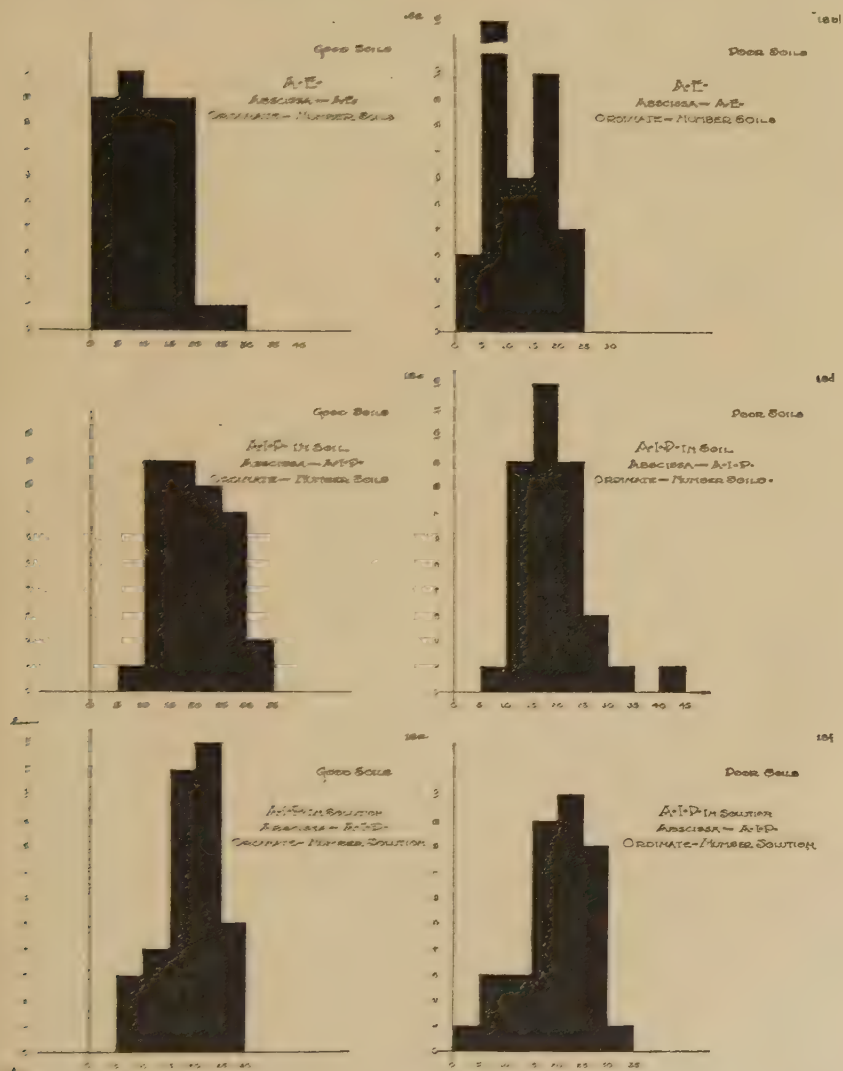
¹ Spillmans and J. C. De Ruijter De Wildt. Derstg. Land. Ind. Rijks. Netherlands. 1907.

² Borden and Davis. Principles of Botany. p. 233.

³ Franz Lefar. Technical Mycology, Eng. Ed., 1898. Vol. I, p. 332.

⁴ E. B. Voorhees and J. G. Lipman. N. J. Sta. Bul. 221.

and ammonium sulphate it was found that during the first two periods each covering five years sulphate of ammonia gave a slightly larger yield. During the last three five-year periods nitrate of soda gave larger yields."⁵



"From the Rothamstead experiments it is found that nitrate of soda affords the better sources of nitrogen for wheat grass and manigolds, the superiority amounting to about 10 per cent, but that for barley, potatoes, and turnips, the two manures are of equal value, nitrogen for nitrogen.

"In the experiments with barley covering a period of fifty years the average of the first thirty years shows 5.6 per cent in favor of nitrates and for the last twenty years an average of .8 per cent in favor of sulphate of ammonia, when supplied in addition with superphosphates and potash. In all the comparative tests when potash was omitted the odds were very much in favor of nitrates.

"For 1900, the twenty-fifth year of a comparative test with manure the odds in favor of nitrates were 29.6 tons against 28.2. When used alone nitrate of soda for twenty-seven years has an annual average to its credit of 4.25 tons.

"The average yields of wheat for twenty-two years with nitrates in a complete fertilizer was 28.7 bu. Ammonia with complete fertilizer was 23.4 bu.

"The average of barley for 51 years with

Nitrate in a complete fertilizer was.....	43.5
Ammonia in a complete fertilizer was.....	42.1

"The average of marigolds for 27 years with

Nitrate in a complete fertilizer was.....	18.01 tons.
Ammonia in a complete fertilizer was.....	14.86 tons." ⁶

"Many of the higher green plants prefer their nitrogenous food in the form of nitrates. (Example, nitrate of soda, potassium nitrate.) The fact that this nitrification is going on constantly in soil is of the utmost importance, for while commercial nitrates are often applied to the soil, the nitrates are easily washed from the soil by heavy rains."⁷

"As a fertilizer the special value of nitrate of soda lies in its nitrogen being in a form (nitrate) immediately available as plant food. On the other hand, ammonium sulphate and dried blood will only become available after being acted upon by bacteria which convert their nitrogen into a form absorbable by plants."⁸

Vogel¹⁰ found that the productivity of soils under his investigations bore a direct relation to nitrifying energy.

The last author does not, however, accord the large returns from any crop when fed ammonia salts to the direct assimilation of the salt itself, but to the changing of the same *to nitrate by nitrification*, which he claims may take place immediately and in enormous amounts. The following quotation illustrates his views:

"This view, however, forgets that if the ammonium salts are to be fed the plant that they must be nitrified. As a nitrogenous manure sulphate of ammonia is practically as effective, nitrogen for nitrogen, as nitrate of soda; it is also to all intents and purposes as rapid in its action, *because the process of nitrification*, which generally precedes the utilization of the ammonia by the plant, takes place very rapidly in suitable soil."

⁶A. D. Hall. Fertilizers and Manures.

⁷Atkinson, College Botany, p. 83.

⁸Report of the Government Bureau of Microbiology for 1909, p. 133. New South Wales.

¹⁰Vogel Mit de Kais. W. Inst. f. Lond. in Bromberg, B. 2, heft 4, p. 419.

Hall cites the following from Woburn Station as proof. The addition of lime making the conditions suitable for nitrification.

<i>Barley.</i>	<i>Bushels per Acre.</i>	
	<i>No Lime.</i>	<i>After Liming.</i>
Minerals + Ammonium salts	1.8	23.9
Minerals + Nitrate of soda.....	24.7	

"Sulphate of ammonia * * * must be nitrified before the nitrogen is available to plants."¹¹

"It is sufficient to emphasize the importance of the process of nitrification to the growing crop. So vital indeed is the subject that successful agriculture may be said to depend largely upon providing proper conditions for rapid nitrification."¹²

"Mention has repeatedly been made of the fact that the plant can make use of the nitrogen only when it is present in the soil in the form of nitrates. * * * All the other materials must undergo the process of nitrification and have their nitrogen converted into nitrates before they can be used by the crop."¹³

"The nitro-bacteria are of great importance in the economy of nature by providing a continual supply of nitrates to the soil."¹⁴

"The conversion of the ammonia formed during the process of putrefaction into the nitrates is a matter of the greatest importance in soil fertility. * * * A soil to encourage nitrification must, then, have a suitable basis. The question of soil fertility is, then, in its last analysis a bacteriological problem."¹⁵

"The importance of nitrification will be understood when I say that it is almost exclusively in the form of nitrates that all ordinary farm crops, except legumes, take up their nitrogen.

"I can not here give the details of my researches, but I think my experiments have proved conclusively that not only are the nitrifying bacteria present in abundance, but they are in a state of great activity, and I have been forced to the conclusion that, with the higher temperature in the Transvaal, nitrification proceeds much more rapidly here than in temperate countries.

"I examined some soils which had been kept in 'an air-dry' state in tightly-corked bottles in our laboratories for over five years, and in every case the organisms were found to be present.

"In only two soils in the whole course of my experiments did I fail to find the bacteria in abundance. Both of these were 'vlei' soils, which had probably been in a water-logged state for years, and which contained too much organic matter and too little lime to promote nitrification."¹⁶

Numerous investigations during recent years have been conducted to determine whether other forms of nitrogen than the nitrate can be used by plants. Typifying these are the following quotations:

¹¹John Percival's *Agricultural Bacteriology*, p. 142.

¹²Vivian, Alfred, *First Principles of Soil Fertility*, p. 23, 1909.

¹³Vivian, Alfred, *First Principles of Soil Fertility*, 1909, pages 193, 194.

¹⁴Pfeffer, *Physiology of Plants*, Eng. I, 361, 1900.

¹⁵Frost and MacCampbell, *Genl. Bacteriology* (1910), p. 288.

¹⁶Robert C. Watt. Notes from the Chemical Laboratories. Nitrification in Transvaal Soils.

"The recent comprehensive researches of Pitsch and Maze have conclusively proved that the nutritive value of ammonia must not be entirely denied; in the majority of green plants it is second only to nitric acid in value. In the case of some plants, particularly maize and other Gramineal ammonia is by no means of inferior value to nitric acid. Similar results were obtained in cultures of *Brassica* and species of *Allium*. Forest trees also must be dependent on ammonia since nitrates are seldom present in woodland soils. So far as we know at present it is quite certain that in addition to plants which definitely prefer nitric acid, there are others which get along just as well or even better with ammonia."¹⁷

"Muntz, of the Agricultural Institute of Paris, has demonstrated the falsity of this view (that plants utilize ammonia only after its oxidation and transformation to nitrates.) He grew plants in a soil deprived of nitrates by prolonged leaching and freed from nitrifying ferments by the action of heat. He also took special precautions to prevent the introduction of these ferments during the course of the experiment. The plants were enclosed in glass vessels, and the air supplied to them was conducted through glycerin in order to remove all dust which might carry in the nitrifying germs."¹⁸

Basing his results on a large number of experiments on paddy rice, both in paddy rice soils and upland soils, M. Nagaoka makes the following conclusions:

"It was sufficiently proved in all of the preceding trials that paddy plants can not utilize nitric nitrogen as well as ammoniacal nitrogen.

"As to the relative value of the nitric and ammoniacal nitrogen upon the paddy rice plant *Juncus* and Arrowhead it is seen that for one hundred of the ammoniacal nitrogen the nitric nitrogen had the following value:

With paddy rice	40
With <i>Juncus</i>	37
With Arrowhead	33"

As to the possibility of the ammoniacal nitrogen being changed into nitrates by the process of nitrification, the author has the following to say:

"However, as a whole in all irrigated soils the so-called process of nitrification does not generally take place * * * hence such conditions of soil might generally be supposed to be provided with ammoniacal nitrogen alone."

As evidence of this may be cited the relatively larger returns from the ammoniacal nitrogen under irrigated conditions than when not irrigated, the latter supposedly being better suited to the process.¹⁹

Very recently Hutchinson and Miller of the Rothamstead Experiment Station,²⁰ in a very carefully planned and executed experiment

¹⁷Ludwig Jost, Lectures on Plant Physiology, 1907, p. 135.

¹⁸P. Deherain, Nitrification in Arable Soil. Exp. Rec., Vol. VI, p. 354.

¹⁹M. Nagaoka on the Behavior of the Rice Plant to Nitrates and Ammonium Salts. Bull. Tokyo Coll. of Agric., Vol. VI, 1904.

²⁰Hutchinson and Miller, Jour. and Agr. Sc., III, 1909.

have clearly demonstrated that wheat can utilize ammonia nitrogen when all possibility of nitrification has been excluded.

From the results of Kruger,²¹ showing a difference in different crops as to the form in which they can utilize nitrogen, it would be extremely unsafe to extend Miller's conclusion to any other crop than wheat without experimental demonstration.

Wagner²² has clearly shown that in field practice nitrate nitrogen produces better yields than ammonia nitrogen.

In these and practically all similar experiments, however, the possibility of nitrification was not excluded and no note of the nitrifying power of the soils was made. No conclusion can therefore be drawn as to whether those plants actually used the ammonia nitrogen or whether it was first converted into nitrate nitrogen by nitrification.

Summarizing present knowledge upon this point, it may be said that it has been definitely shown (1) that some plants can utilize ammonia nitrogen; (2) that there is a difference between plants of different species as to which is the most appropriate form of nitrogen; (3) that in field and pot tests, nitrification not regarded, nitrate nitrogen usually gives larger returns than ammonia nitrogen.

Two points upon which information is sorely needed are:

1. Knowledge of the form of nitrogen best adapted to each species of crop plant.

2. Knowledge as to the necessity of nitrification preliminary to the utilization of ammonia nitrogen by crop plants.

A series of experiments has now been in progress some years which it is hoped may throw light upon these questions.

In all cases, if any such exist, of crops which can not use ammonia nitrogen the ability of the soil to nitrify is essential to crop production. In all cases of crops which can utilize nitrate nitrogen to appreciably better advantage than ammonia nitrogen the ability to nitrify is of value since it increases the return from all organic or ammonia nitrogen applied.

In either of the two above cases the increase of a low N. E. and especially the increase from no appreciable N. E. to an efficient N. E. is an important desideratum.

INCREASING THE N. E. OF SOILS.

The low N. E. of the soils examined may be referred to one of two reasons.

1. The absence of suitable organisms i. e., low N. I. P.

2. Absence of suitable condition for the growth and functioning of the nitrifying organisms, i. e. too low N. C.

Whichever of these conditions actually obtains today it is reasonable to assume that if the soil be made highly suitable to the growth of the nitrifying organisms these organisms will eventually and naturally find their way into those soils.

²¹Kruger, W. Lander, Jahr 34, 761, 1905.

²²Wagner, P., Arb. d. Deut. Land Ges. Heft 159, p. 207, (1907)

Kellerman and Robinson²³ have reported higher N. E. in North Carolina soils than our own analyses show either when determined by their method or ours. They were working with soils from fields bearing crimson clover. Crimson clover in North Carolina stands for a high type of farming and without further evidence it is fairly allowable to assume that crimson clover fields in general are attended by good farmers and that the fields are above the average in fertility. Their findings compared with ours, therefore, substantiate the conclusion that the N. E. of soils can be in general increased by good culture. Kellerman and Robinson attach principal importance to legumes and especially to the presence of root tubercles in this connection. Scrutiny of our tables shows the following:

RELATION OF N. E. TO LEGUME CROPS AND TO MANURE USED.

Of 23 soils known to have had a legume growing on them during the past three seasons 7 or 31.43 per cent showed N. E. Five or 18 per cent showed N. E. greater than 2.

Of 14 soils known to have had an application of manure during the past three seasons 6 or 42.85 per cent showed N. E. Two or 14 per cent showed N. E. greater than 2.

Of 52 on which no legume was reported 13 or 25 per cent showed N. E. Three or 5.7 per cent showed N. E. greater than 2.

Of 59 on which no application of manure was reported 14 or 23.81 per cent showed N. E. Six or 10 per cent showed N. E. greater than 2.

It is seen that legume bearing soils do have higher N. E. than non legume bearing soils in the ratio of 31.43 to 25, or N. E. greater than 2 in the ratio of 18 to 5.7.

A similar fact appears regarding the use of stable manure.

Fields with stable manure show N. E. in 42.85 per cent of the cases while fields with no stable manure show N. E. in only 23.81 per cent of the cases or N. E. greater than 2 in 14 per cent as against 10 per cent.

It thus appears that these two factors, legumes and stable manure, are probably of approximately equal value in increasing N. E. The other factors which enter into this question are yet but imperfectly known. Of the inter-relations between the complex bacterial flora we can not even hazard a guess. Whether inoculation with suitable organisms of high nitrifying power would aid in establishing a high N. E. and if so whether the N. E. so attained would be permanent is unknown.

Experiments which have been under way some two years upon these last two points may aid in solving the question.

²³Kellerman, K. F., Robinson, T. R., Science Ns. 30 (1909) p. 414.

No.	Yielding Power Per Acre.			Crop Raised.			Fertilizer.			Soil Records.										I. P. in Sol.						No.		
	Corn. Bu.	Cotton. Lbs.	Other Crop.	1909.	1908.	1907.	1909.	1908.	1907.	Lab. No. (W)	Assm. No. (S)	Date Collected.	Date Set Up.	Collector.	County.	Quality.	Classification.		1909.	1910.	1909.	1910.	1909.	1910.	A. E.		A. I. P. in Sol.	A. I. P. in Sol.
																	Collector's.	McNider's.										
1	40	1,500		Peanuts.	Cotton.	Peanuts.	Li. and plas.	A. and m.	Li. and plas.	285	255	3-4-09	3-8-09	Brown	Hertford	Rich.	Loam	N. S. L.	1.8			72.5	1.5	6.03				1
2	15	700		Cotton.	Peanuts.	Cotton.	A. m. and K.	Li. and p.	Fertilizer.	286	256	3-4-09	3-8-09			Poor.	Loam	N. S. L.	17.3			66.5	1.5	6.40				2
3	40	1,000		Garden.	Garden.	Garden.	M. and fert.	F. and m.	M. and fert.	304	259	3-13-09	3-18-09	Stevens	Johnston	Good.	N. S. L.	N. S. L.	5.48					15.85				3
4	12	400		Cotton.	Cotton.	Cotton.	Fertilizer.	Fertilizer.	Fertilizer.	305	260	3-13-09	3-18-09			Poor.	N. S. L.	N. S. L.						15.89				4
5	50	1,500	40,000 cukes.	Vel. beans.	Cannas.	Cannas.	Fert. 2000.	Fert. 2000.	Fert. 2000.	309	261	3-17-09	3-22-09	Taylor	Duplin	Good.	N. F. S.	N. F. S.	5.48	6.5	4.74	74.1	1.5	3.21				5
6	1	140	1,000 cukes.	Vel. beans.	Cannas.	Cannas.	Fert. 2000.	Fert. 2000.	Fert. 2000.	310	262	3-17-09	3-22-09			Poor.	N. F. S.	N. F. S.	0.5+			23.8	1.5	1.93				6
7	60	2	High.	Corn.	Corn.	Garden.	M. 0	M. 0	M. 0	337	265	3-29-09	4-5-09	Collett	Buncombe	Rich.	Prs. L.	P. L.	21.1			92.1	5.02	0.0	6.23	14.00	17.08	7
8	30	?	10 bu. wheat.	Corn.	Corn.	Wheat.	0	0	0	338	266	3-29-09	4-5-09			Poor.	Prs. L.	P. L.	-0.8				0.0	6.93	14.35	25.61	8	
9										350	269	4-10-09	4-15-09	Scott	Edgecombe	Good.	N. S. L.	N. S. L.							10.50	18.55	20.48	9
10										351	270	4-10-09	4-15-09			Poor.	N. S. L.	N. S. L.							12.04	15.40	18.72	10
11	42	1,100	23 bu. wheat.	Corn.	Cotton.	Wheat and peas.	Fertilizer.	Fertilizer.	Fertilizer.	354	271	4-10-09	4-19-09	Meecham	Iredell	Good.	C. C.	C. C.	2.0			41.1	0.38	0.2	10.80	15.40	19.89	11
12	9	500	2 bu. wheat.	Corn.	Cotton.	Wheat and peas.	0	0	0	353	272	4-10-09	4-19-09			Poor.	C. C.	C. C.	1.0			4.5	0.46	0.2	6.67	14.53	25.93	12
13	30	1,500	85 bu. peanuts.	None.	Corn.	Peanuts.	None.	None.	L. plas.	360	274	4-22-09	4-26-09	Bachman	Chowan	Good.	N. F. S. L.	N. F. S. L.	0.00			51.4	4.48	0.5	17.95	21.71	14.64	13
14	15	1,000	100 bu. peanuts.	None.	Corn.	Corn.	None.	A. & M.	None.	361	275	4-22-09	4-26-09			Poor.	N. F. S. L.	N. F. S. L.	0.00			72.4		0.6	15.75	12.95	11.66	14
15	25	1,500		Corn and pota.	Cotton.	Cotton.	Fert. and m.	F. and m.	Fert. and m.	376	276	5-3-09	5-3-09	Pearce	Duplin	Rich.	P. L. S.	N. S. L.	-2.0			7.3		0.0	15.76	14.35	21.06	15
16	6	300		Corn.	Cotton.	Corn.	Fert. and m.	Fertilizer.	Fertilizer.	377	277	5-3-09	5-3-09			Poor.	P. L. S.	N. F. S.	-1.5			4.8		0.1	22.71	14.35	23.40	16
17	23	900	Fine cow peas.	Cotton.	Corn.	Cotton.	Fert. 400.	Fert. 200.	Fert. 400.	386	278	5-5-09	5-6-09	Drane	Pitt	Good.	N. F. S. L.	N. F. S. L.	-7.4			22.9		0.1	14.21	13.50	8.18	17
18	12	600	Good cow peas.	Cotton.	Corn.	Corn.	Fert. 400.	Fert. 200.	Fert. 400.	387	279	5-5-09	5-6-09			Poor.	N. F. S. L.	N. F. S. L.	1.4+			78.0		0.1	10.53	16.40	19.85	18
19	75	1,500								396	280	5-10-09	5-10-09	Gainey	Wake	Good.	M.	M.	2.2			18.7		1.5	7.67	19.92	18.65	19
20	50	1,000								397	281	5-10-09	5-10-09			Poor.	M.	M.	13.3			87.5		1.5	8.33	18.10	22.50	20
21	23	1,600	1,000 lbs. tob.	Tobacco.	Tobacco.	Corn.	Fert. 1,000.	Fert. 1,000.	0	401	282	5-12-09	5-13-09	Drane	Pitt	Good.	N. V. F. S. L.	N. V. F. S. L.	-0.3			11.3		0.1	7.03	20.20	12.40	21
22	12	800	600 lbs. tob.	Corn.	Peanuts and mola.	Fallow.	0	0	0	402	283	5-12-09	5-13-09			Poor.	N. V. F. S. L.	N. V. F. S. L.	-2.0			28.7		0.1	6.86	14.67	10.41	22
23	75	1,600								403	284	5-13-09	5-13-09	Gainey	Wake	Good.	C. S. L.	C. S. L.	0.00			58.8		1.5	10.22	12.88	21.06	23
24	25	500								404	285	5-13-09	5-13-09			Poor.	C. S. L.	C. S. L.	0.00			58.2		1.5	10.22	12.88	21.06	24
25	30	1,500	Good peas.	Corn.	Peanuts.	?	F. and m.	?	?	408	286	5-13-09	5-17-09	Middleton	N. Hanover	Good.	N. S. L.	N. S. L.						0.77	27.31			25
26	Searcely	nothing.		Potatoes.	Peanuts.	?	M. and m.	None	?	409	287	5-13-09	5-17-09			Poor.	N. S. L.	N. S. L.						9.70	44.77			26
27	40	1,500	80 bu. peanuts.	Corn.	Cotton.	Corn.	0	Fert. 4,000.	0	415	288	5-14-09	5-20-09	Bachman	Perquimans	Good.	P. S. L.	P. F. S. L.						10.15	14.35	24.57	27	
28	12	500	50 bu. peanuts.	Corn.	Corn.	Corn.	0	Fish st.	0	416	289	5-14-09	5-20-09			Poor.	P. S. L.	P. F. S. L.	11.47					14.70	22.17		28	
29	75	2,000	High.	Beans and pota.	Corn and peas.	Corn and peas.	Fert. 1,000.	Fert. 600.	Fert. 600.	422	290	5-20-09	5-24-09	Ireland	Duplin	Good.	O. F. S. L.	O. F. S. L.	16.13	0.00		3.5		0.1	15.05	25.58	24.57	29
30	25	1,000	Not very.	High-beans.	Pota. and corn.	Corn and peas.	Fert. 1,000.	Fert. 600.	Fert. 600.	423	291	5-20-09	5-24-09			Poor.	O. F. S. L.	O. F. S. L.	3.5			86.7		0.1	23.07	26.26	19.99	30
31	40	900	30 bu. wheat.	Corn.	Wheat.	Clover.	F. and m.	F. and m.	0	433	292	5-17-09	5-31-09	Hornaday	Alamance	Good.	C. C.	C. C.	39.46	36.1	2.00	78.7	2.00	0.21	14.28	11.94	19.98	31
32	7	300	5 bu. wheat.	Clover pas.	Wheat.	Corn.	0	F. and m.	Fert. and m.	434	293	5-17-09	5-31-09			Poor.	C. C.	C. C.	2.00	11.7	2.00	54.4	2.00	0.0	6.14	13.51	21.06	32
33			None in cultivation.							435	294	5-19-09	5-31-09	Humphrey	Craven		Sva.	Sva.						3.46	14.80	22.59	33	
34			None in cultivation.							436	295	5-19-09	5-31-09				Pen.	Pen.						15.75	18.03	16.26	34	
35	60	2,000	Good.	Beans and annas.	V. beans.	Cannas.	Fert. 1,500.	Fert. 500.	Fert. 1,500.	440	296	5-22-09	6-1-09	Taylor	Duplin	Rich.	P. S.	P. S.	29.73	10.6	5.20	87.7		1.5	17.65	22.16	19.65	35
36	1	50	Very poor.	Beans and annas.	V. beans.	Cannas.	Fert. 1,500.	Fert. 500.	Fert. 1,500.	441	297	5-22-09	6-3-09			Very poor.	P. S.	P. S.	0.1	0.10		5.5		1.5	8.78	16.10	21.99	36
37	35	?	14 T. hay.	Rye and corn.	Rye and beans.	Corn.	8 tons.	Fert. 400.	Li. 15 bu.	442	298	5-22-09	6-3-09	Merchant	Henderson	Rich.	Prs. S. L.	Prs. S. L.	2.	1.3+		40.3		0.0	15.98	18.45	24.57	37
38	5	?	1 T. hay.	Peas.	0	0	0	0	0	443	299	5-22-09	6-3-09			Poor.	Prs. S. L.	Prs. S. L.	1.4+			6.4		0.0	6.72	16.45	18.72	38
39	15	1,000	15 bu. wheat.	Wheat and corn.	Wheat and corn.	Wheat and corn.	Fertilizer.	Fertilizer.	Fertilizer.	450	300	5-27-09	6-7-09	Moore	Caldwell	Good.	Cno. C.	Cno. C. L.	105.1	0.10	0.10	80.7	0.10	0.1	20.82	25.06	19.98	39
40	10	1,000	5 T. wheat.	Wheat.	Oats.	Corn.	Fertilizer.	Fertilizer.	Fertilizer.	451	301	5-27-09	6-7-09			Poor.	Cno. C.	Cno. C. L.	0.1			30.0	0.10	0.1	7.53	15.19	15.44	40
41	40	?	?	Corn.	Corn.	Corn.	Lime.	Lime.	Lime.	452	302	5-27-09	6-7-09	Drane	Pitt	Good.	P. L.	P. L.	-8.0	0.00		30.6		0.1	16.97	26.43	22.82	41
42	42	1,300	30 bu. oats.	Cotton.	Cotton.	Cotton.																						

VI.—STUDIES IN SOIL BACTERIOLOGY

MISCELLANEOUS NITRIFICATION EXPERIMENTS,

BY

F. L. STEVENS AND W. A. WITHERS,

ASSISTED BY

P. L. GAINEY, J. K. PLUMMER, F. W. SHERWOOD, T. B. STANSEL AND
C. E. BELL.

In the course of a series of investigations extending over a period of several years certain experiments have been made, the results of which, while unrelated and not forming part of the major subject under investigation, still possess some interest and value. It is thought wise to bring these together in the present form.

TO COMPARE THE INHIBITING EFFECT OF AMMONIUM SULPHATE IN SOIL AND
IN SOLUTION.

Experiment No. 273. May, 1909.

Six Erlenmeyer flasks were filled with 400 grams of sterile soil 1931 in the usual way with 240 mgs. of nitrogen added as sterile ammonium sulphate solution. To each was added additional sterile ammonium sulphate in the amounts indicated in the table varying from 0 per cent to 5 per cent based upon the total amount of water in the medium.

Six flasks were similarly set up with Omeliansky's solution instead of soil as the medium, these also bearing corresponding amounts of additional ammonium sulphate.

The whole series was also set up to run three months before analysis. All flasks were inoculated in the usual manner with a strongly nitrifying soil (Georgia No. 1). Analyses were made at one month on one series, at three months on the other.

The results are presented in Table I.

The results in solution at the end of the shorter period of incubation, 28 days, are of little value since nitrification was very tardy. Retardation at 28 days is noted in soil in the presence of 0.5 per cent or more "additional" ammonia, in the soil. At the end of twelve weeks decided retardation is evident when there was "additional" ammonia to the amount of 0.5 per cent or more and complete inhibition resulted from the presence of 5 per cent.

In solutions at 12 weeks retardation is evident if amounts of 1 per cent or more "additional ammonia" are present. If the nitrification be based upon the total amount of ammoniacal nitrogen present the same generalizations are maintained though it would then appear as though the retardation were greater in the solutions than in the soils.

TABLE I—EXPERIMENT 273. Inhibiting effect of Ammonium Sulphate in soil and in solution.

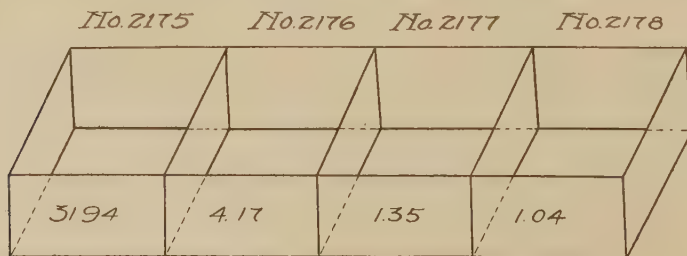
RESULT OF ANALYSIS.

Flask No.	Medium.	Percent of Additional Ammonium Sulphate.	Incubation, Days.	Per Cent Based on Total Initial Nitrogen.	
				Recovered as:	
				Nitrite.	Nitrate.
1	Soil.	0.0	28	0.00	19.42
2	do.	0.01	28	0.00	18.90
3	do.	0.1	28	0.00	14.24
4	do.	0.5	28	0.00	0.00
5	do.	1.0	28	0.00	0.00
6	do.	5.0	28	0.00	0.10
7	Omeliarsky's solution.	0.0	28	0.00	0.10
8	do.	0.01	28	0.00	0.10
9	do.	0.1	28	0.00	0.52
10	do.	0.5	28	0.00	0.10
11	do.	1.0	28	0.00	0.10
12	do.	5.0	28	0.00	0.10
13	Soil.	0.0	84	1.00	40.09
14	do.	0.01	84	1.00	37.60
15	do.	0.1	84	1.00	34.18
16	do.	0.5	84	1.00	18.51
17	do.	1.0	84	1.00	1.00
18	do.	5.0	84	1.00	0.00
19	Omeliarsky's solution.	0.0	84	1.00	13.86
20	do.	0.01	84	1.00	7.02
21	do.	0.1	84	1.00	8.11
22	do.	0.5	84	1.00	3.81
23	do.	1.0	84	1.00	1.53
24	do.	5.0	84	1.00	1.00

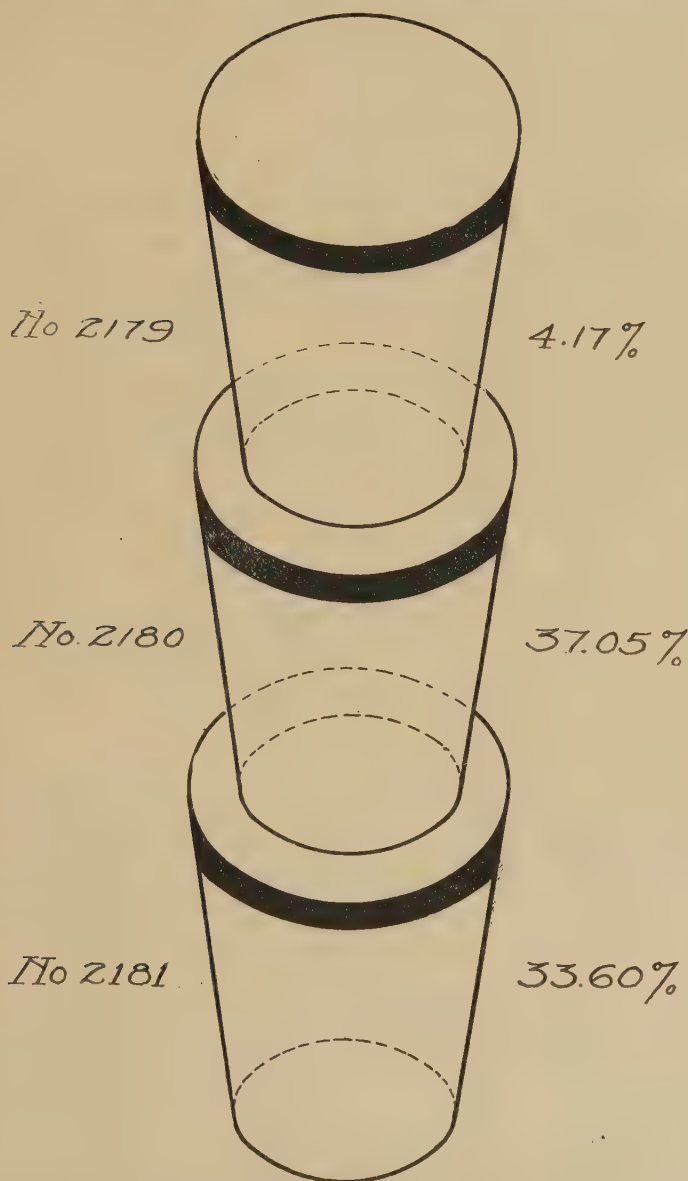
MIGRATION OF NITRIFYING BACTERIA IN SOIL.

Experiment No. 79. February 24, 1908.

To test horizontal migration a series of four samples of soil No. 1867, identical except for the inoculum added, was set up as is shown in the accompanying diagram, the four samples being included in a tight, rectangular oak box with open top. The partitions between the several



compartments were of rather coarse iron gauze. The samples were so packed in the compartments as to bring the soil in one compartment closely in contact with the soil of the adjacent compartment. Each lot



of soil contained 240 mgs. nitrogen as ammonium sulphate. The soil in compartment No. 2175 was thoroughly inoculated with a suspension taken from a vigorously nitrifying soil. Lots 2176, 2177, and 2178 were

not inoculated. Analysis was made at the end of eight weeks. The results are presented in table 2.

To test vertical migration three flower pots were taken and placed one above the other. In each was placed the same amount of soil initial nitrogen and there was the same incubation period as in the experiment to test horizontal migration, only 2179 was inoculated with 25 cc. of a suspension of soil 1867.

The results are shown in Table II.

TABLE II.—EXPERIMENT 79.

Date of inoculation, Feb. 24, 1908. Time of incubation, 56 days. Medium, 400 grams sterile soil No. 1867. Nitrogen, 240 milligrams in form of ammonium sulphate.

HORIZONTAL MIGRATION.

Sample Number.	Inoculum, kind.	Quantity.	Percentage of initial nitrogen recovered as:		
			Ammonia.	Nitrite.	Nitrate.
2175	Suspension 1867	25cc	25.91	0.00	31.94
2176	Only from 2175	-----	37.11	0.00	4.17
2177	do. 2176	-----	31.44	0.00	1.35
2178	do. 2177	-----	32.91	0.00	1.04—

VERTICAL MIGRATION.

2179	Suspension 1867	25cc	13.30	0.00	4.17
2180	Only from 2179	25cc	34.22	0.00	37.05
2181	do. 2180	25cc	39.91	0.00	33.60

It is seen that within the duration of the experiment there was little, possibly no, migration of the nitrifying organisms from one compartment to another, the small amount of nitrate that passed to the lateral or lower compartments being perhaps more readily explained on the basis of diffusion of nitrate than on the hypothesis of germ migration.

EFFECT OF DRYING UPON N. E. AND N. I. P.

Experiments 252 and 253. May, 1909.

Two soils, No. 1867 and Georgia No. 1 were tested for N. E. and N. I. P. in the usual way except that no subtraction was made for the control sample in any case. Other samples of the same soils were allowed to air dry in the laboratory for two months and N. E. and N. I. P. were determined in them in the usual way.

Table III shows the N. E. and N. I. P. in the fresh and air dried samples.

It is seen that the two months of drying resulted in no material change in the N. E. of either of these soils. The N. I. P., however, did

TABLE III.—EXPERIMENTS 252 AND 253.

	Soil 1867.		Georgia Soil No. 1.	
	Before Drying.	Dried.	Before Drying.	Dried.
N. E.	67.02	59.82	22.55	18.79
	72.03	61.08	16.91	21.92
Average.....	69.53	60.45	19.73	20.36
N. I. P.	68.90	8.77	47.29	0.00
	66.40	9.40	41.37	0.00
Average.....	67.65	9.09	44.33	0.00

change very materially, dropping in the case of the N. C. soil from 67 to 9 and in the case of the Ga. soil from 44 to zero. The discrepancy between the N. E. and N. I. P., fully sustained as it is by the duplicate samples is peculiar and unexpected.

FURTHER EVIDENCE OF DIFFERENCE BETWEEN N. I. P. IN SOIL AND
IN SOLUTION.

Experiment No. 264. April, 1909.

The N. I. P. of Georgia soil No. 1 was determined both in soil and in solution with the following results.

TABLE IV.—N. I. P. OF GEORGIA SOIL NO. 1.

	Sample No.	Percentage of initial nitrogen recovered as:		
		Nitrites.	Nitrates.	Nitrites and Nitrates.
In soil.....	3729	0.00	12.53	12.53
	3730	0.00	10.65	10.65
	aver.	0.00	11.59	11.59
	3731	0.00	0.00	0.00
	net	0.00	11.59	11.59
In solution.....	3732	tr.	1.91	1.91
	3733	3.50	2.40	5.90
	aver.	1.75	2.16	3.91
	3734	0.00	0.00	0.00
	net	1.75	2.16	3.91

It is to be noted that the N. I. P. while agreeing well in the duplicate samples is far lower when determined in solutions than when determined in soils.

A COMPARISON OF THE METHOD OF KELLERMAN AND ROBINSON WITH THE
STEVENS AND WITHERS METHOD OF DETERMINING NITRIFYING
POWER.

Experiment No. 349. October, 1909.

For this purpose nineteen soils were selected. Four soils were known to bear cowpeas with root tubercles, four crimson clover with tubercles, four vetch with tubercles. Four we had already determined by our own method as low in nitrifying power, while three were on our record as good nitrifiers.

To determine the nitrifying ability of several soils using the method of Kellerman and Robinson, i. e.: to 50 grams of soil exposed to air in inoculating room to dry were added 5 cc. of a 0.4 per cent solution of ammonium sulphate, placed in sterile wide mouth bottles stopped with wet cotton plug and incubated for eight days, September 30 to October 7, 1909. Done in duplicate, one analysed in 0 days. Difference between 0 days and 8 days nitrification. The results are shown in Table V.

TABLE V.—NITRIFICATION. KELLERMAN AND ROBINSON METHOD.

Soil No.			Parts per Million Nitrate Nitrogen.			
			0 Days.	8 Days.	Net.	Average.
6081-2	1 Soil A	Cowpea tubercles present.	2.0—	25.8	23.8	
6083-4	2 Soil B	do.	2.0—	11.0	9.0	
6085-6	3 Soil C	do.	2.0—	9.0	7.0	
6087-8	4 Soil D	do.	2.0—	9.0	7.0	11.7
6089-90	5 Soil E	Crimson clover tubercles.	2.0—	10.5	8.5	
6091-2	6 Soil F	do.	2.0—	9.5	7.5	
6092-4	7 Soil G	do.	2.0—	16.0	14.0	
6095-6	8 Soil H	do.	4.0	26.0	22.0	13.0
6097-8	9 Soil I	Vetch tubercles present.	4.0	25.1	21.1	
6099-00	10 Soil J	do.	2.0—	15.0	13.0	
6101-2	11 Soil K	do.	2.0—	9.0	7.0	
6103-4	12 Soil L	do.	5.0	5.0	0.0	10.3
6105-6	13 Soil 311	Soil Sur. non-nitrifying.	9.0	12.0	3.0	
6107-8	14 Soil 314	do.	5.0	12.5	7.5	
6109-10	15 Soil 315	do.	5.0	14.0	9.0	
6111-12	16 Soil 279	do.	12.0	17.5	5.5	6.2
6113-4	17 Soil 290	Soil Survey nitrifying.	40.0	42.2	2.2	
6115-6	18 Soil 308	do.	23.5	50.0	26.5	
6117-8	19 Soil 310	do.	4.0	228.5	224.5	63.3

The nitrates were determined by the phenol disulphonic acid method. l. c.

It is to be noted that in general the results agree; the soils reported low by one method are shown to be low by the other method though in the Kellerman and Robinson method only one soil gave zero.

Though the samples are not of sufficient number to admit of generalization these results indicate superior nitrifying power in soil that bears tuberculous crops.

Experiment 350, Nitrification. Stevens and Withers Method.

Incubated 4 weeks (Sept. 30 to October 28, 1909). Eleven of the 19 soils used in experiment 349 were used in this experiment and an additional soil (332). The results (N. E.) are shown in Table VI.

TABLE VI.—EXPERIMENT 350, NITRIFICATION.

Lab. No.	Soil No.		Parts per Million Parts of Soil.			Per Cent of Initial N.		
			NO ₂	NO ₃	NO ₂ & NO ₃	NO ₂	NO ₃	NO ₂ & NO ₃
6143	1 E	Crimson clover tubercles present.	0.0	40.0	40.0	0.0	1.50	1.5
6144	2 E	do.	5.4	40.0	45.4	0.28	1.50	1.78
Aver.			2.7	40.0	42.7	0.14	1.50	1.64
6145	3 E	No Am. S. added.	2.0	3.6	5.6	0.1	0.13	0.23
6146	4 E	do.	0.0	4.8	4.8	0.0	0.18	0.18
Aver.		do.	1.0	4.2	5.2	0.05	0.16	0.21
Net-N. E.			1.7	35.8	37.5	0.09	1.34	1.42
6147	5 F	Crimson clover tubercles present.	6.0	3.0	9.0	0.30	0.11	0.41
6148	6 F	do.	2.0	0.0	2.0	0.1	0.00	0.10
Aver.			4.0	1.5	5.5	0.2	0.06	0.26
6149	7 F	No Am. S. added.	0.0	6.0	6.0	0.0	0.23	0.23
6150	8 F	do.	0.0	4.8	4.8	0.0	0.18	0.18
Aver.			0.0	5.4	5.4	0.0	0.21	0.21
Net-N. E.			4.0	3.9	0.1	0.2	0.15	0.05
6151	9 G	Crimson clover tubercles present.	3.5	60.0	63.5	0.18	2.26	2.34
6152	10 G	do.	4.0	48.0	52.0	0.20	1.81	2.01
Aver.			3.8	54.0	57.8	0.19	2.04	2.23
6153	11 G	No Am. S. added.	2.0	6.0	8.0	0.10	0.23	0.33
6154	12 G	do.	2.0	2.4	4.4	0.10	0.09	0.19
Aver.			2.0	4.2	6.2	0.10	0.16	0.26
Net-N. E.			1.8+	49.8	51.6	0.09+	1.88	1.97
6155	13 H	Crimson clover turbercles present.	2.0	96.0	98.0	0.10	3.62	3.72
6156	14 H	do.	2.0	96.0	98.0	0.10	3.62	3.72
Aver.			2.0	96.0	98.0	0.10	3.62	3.72
6157	15 H	No Am. S. added.	2.0	30.0	32.0	0.10	1.13	1.23
6158	16 H	do.	2.0	30.0	32.0	0.10	1.13	1.23
Aver.			2.0	30.0	32.0	0.10	1.13	1.23
Net-N. E.			0.0	66.0	66.0	0.0	2.49	2.49
6159	17 290	Survey nitrifying.	2.0	240.0	242.0	0.1	9.04	9.14
6160	19 290	No Am. S. added.	2.0	159.8	161.8	0.1	6.00	6.10
Net-N. E.			0.0	80.2	80.2	0.0	3.04	3.04
6161	21 308	Survey nitrifying.	66.6	75.0	141.6	3.33	2.83	6.16
6162	22 308	do.	40.0	120.0	160.0	2.00	3.55	5.55
Aver.			53.3	97.5	150.8	2.67	3.19	6.86
6163	23 308	No Am. S. added.	50.0	7.5	57.5	2.50	0.28	2.78
6164	24 308	do.	28.0	8.6	36.6	1.40	0.23	1.63
Aver.			39.0	8.1	47.1	1.95	0.26	2.21
Net-N. E.			11.3	89.4	100.7	0.72	2.93	3.65

TABLE VI.—EXPERIMENT 350, NITRIFICATION—*Continued.*

Lab. No.	Soil No.		Parts per Million Parts of Soil.			Per Cent of Initial N.		
			NO ₂	NO ₃	NO ₂ & NO ₃	NO ₂	NO ₃	NO ₂ & NO ₃
6165	25 310	Survey nitrifying.	80.0	300.0	380.0	4.0	11.36	15.36
6166	27 310	No Am. S. added.	2.0—	4.8	6.8—	0.1—	0.18	0.28—
Net-N. E.			78.0+	295.2	373.2+	3.9+	11.18	15.08
6167	29 332	Survey nitrifying.	0.0	60.0	60.0	0.00	2.27	2.27
6168	30 332	do.	0.0	30.0	30.0	0.00	1.13	1.13
Aver.			0.0	45.0	45.0	0.00	1.70	1.70
6169	31 332	No Am. S. added.	0.0	48.0	48.0	0.00	1.81	1.81
6170	32 332	do.	0.0	34.2	34.2	0.00	1.29	1.29
Aver.			0.0	41.1	41.1	0.00	1.55	1.55
Net-N. E.			0.0	3.9	3.9	0.00	0.15	0.15
6171	33 311	Survey non-nitrifying.	0.0	60.0	60.0	0.00	2.26	2.26
6172	34 311	do.	0.0	24.0	24.0	0.00	0.90	0.90
Aver.			0.0	42.0	42.0	0.00	1.58	1.58
6173	35 311	No Am. S. added.	0.0	60.0	60.0	0.00	2.26	2.26
6174	36 311	do.	0.0	48.0	48.0	0.00	1.81	1.81
Aver.			0.0	54.0	54.0	0.00	2.04	2.04
Net-N. E.			0.0	—12.0	—12.0	0.00	—0.46	—0.46
6175	37 314	Survey non-nitrifying.	2.0—	96.0	98.0—	0.10—	3.62	3.72—
6176	38 314	do.	2.0—	6.0	8.0—	0.10—	0.23	0.33—
Aver.			2.0—	51.0	53.0—	0.10—	1.98	2.08—
6177	39 314	No Am. S. added.	2.0—	20.0	22.0—	0.10—	0.75	0.85—
6178	40 314	do.	2.0—	12.0	14.0—	0.10—	0.45	0.55—
Aver.			2.0—	16.0	18.0—	0.10—	0.60	0.70—
Net-N. E.			0.0	35.0	35.0	0.00	1.38	1.38
6179	41 315	Survey non-nitrifying.	0.0	4.8	4.8	0.00	0.18	0.18
6180	42 315	do.	0.0	7.2	7.2	0.00	0.27	0.27
Aver.			0.0	6.0	6.0	0.00	0.23	0.23
6181	43 315	No Am. S. added.	0.0	24.0	24.0	0.00	0.90	0.90
6182	44 315	do.	0.0	12.0	12.0	0.00	0.45	0.45
Aver.			0.0	18.0	18.0	0.00	0.68	0.68
Net-N. E.			0.0	—12.0	—12.0	0.00	—0.45	—0.45
6183	45 279	Survey non-nitrifying.	2.0—	48.0	50.0—	0.10—	1.80	1.90
6184	46 279	do.	40.0	60.0	100.0	2.00	2.26	4.26
Aver.			21.0—	54.0	75.0—	1.05—	2.03	3.08
6185	47 279	No Am. S. added.	0.0	34.2	34.2	0.00	1.29	1.29
Net-N. E.			21.0—	19.8	40.8—	1.05	0.74	1.79

NOTE: Phenol disulphonic acid method was used for these determinations. l. c.

NOTE: The averages of N. E. are:

Crimson clover.....	4.48
Survey nitrifying.....	5.48
Survey non-nitrifying.....	0.57

Tabulating the net results of Tables V and VI for purposes of comparison we have Table VII.

TABLE VII.—Parts per million parts of soil.

Soil No.	8 Days NO ₃ *	Rank.	4 Weeks NO ₃	Rank.	4 Weeks NO ₂ & NO ₃ †	Rank.
E	8.5	6	35.8	6	37.2	7
F	7.5	7-8	-3.9	11-12	0.1	10
G	14.0	4	49.8	5	51.6	5
H	22.0	3	66.0	4	66.	4
290	2.2	11	80.2	3	80.2	3
308	26.5	2	89.4	2	100.7	2
310	224.5	1	295.2	1	373.2	1
332	-45.1	12	3.9	11-12	309.	9
311	3.0	10	-12.0	9-10	-12.	11-12
314	7.5	7-8	35.0	7	35.	8
315	9.0	5	-12.0	9-10	-12.	11-12
279	5.5	9	19.8	8	40.8	6

*Stevens and Withers N. E. method.

†Kellerman and Robinson method.

Comparing the rank of the soils regarding nitrates at eight days and at four weeks it is noted that six soils have different rank at these intervals with the additional time of the four-week period. One soil, No. 90, has changed its rank from 11 to 3. The change made by soils Nos. G and H 279 is insignificant. Soil F is reduced from a rank of 7 to that of 11. Soil 315 from 5th rank to 10th rank.

It is apparent from this that a comparison of the nitrates accumulated in a soil at the end of one time interval can not be used as an index of the amount that might be produced in the soil in some other time interval, though in general there is a fairly good agreement between the ranks of the soils at the end of the eight day and the four week intervals. As might be expected there are other changes in rank if the comparison be based on nitrate at the eight day interval and the nitrate and nitrite at the four week interval, which is really a comparison of the results by the method of Kellerman and Robinson with our N. E. method. For example, two changes in rank from 7-8 to 10, 279 changes from 9 to 6, 290 from 11 to 3, and 332 from 12 to 9.

TO DETERMINE THE DIFFERENT EFFECTS ON NITRIFICATION OF VARIOUS AMOUNTS OF AMMONIUM SULPHATE IN SOIL.

Experiment 352, January 13, 1910, and Experiment 463, March 2, 1911.

To determine the relation of nitrification to amount of ammonium sulphate added, when used both in smaller and larger quantities than 240 mg. nitrogen per 400 grams of soil. Sterile soil 1931 and nitrogen in varying amounts and 75 cc. suspension of Georgia soil No. 1 as inoculum were used, and incubated four weeks. Results are shown in Table VIII.

TABLE VIII.—A comparison of the results using different amounts of initial added nitrogen.

EXPERIMENT 352.

Lab. No.	Mgs. N. as Am. S.	Pts. N. P. M. Recovered as:			Per cent. Initial added N. recovered as:
		NO ₂	NO ₃	NO ₂ & NO ₃	NO ₂ & NO ₃
6333	2	0.45	48.39	-----	-226.2
6334	2	0.45	40.89	-----	
Aver.		0.45	44.64	45.09	
6347-48	0	2.19	54.21	56.40	
Net.		-1.74	-9.57	-11.31	
6335	20	0.45	86.00	-----	52.6
6336	20	0.45	78.50	-----	
Aver.		0.45	82.25	82.70	
6347-48	0	2.19	54.21	56.40	
Net.	0	-1.74	28.04	26.30—	
6337	60	0.45	157.35	-----	68.3
6338	60	0.45	161.10	-----	
Aver.		0.45	159.23	159.68	
6347-48	0	2.19	54.21	56.40	
Net.		-1.74	105.02	103.28—	
6339	120	0.45	366.00	-----	96.9
6340	120	0.45	33.90	-----	
Aver.		0.45	349.95	350.40	
6347-48	0	2.19	54.21	56.40	
Net.		-1.74	295.74	294.00—	
6341	240	2.34	476.40	-----	75.2
6342	240	2.25	492.60	-----	
Aver.		2.30	484.50	486.80	
6347-48	0	2.19	54.21	56.40	
Net.		0.11	430.29	430.40—	
6343	480	12.84	560.40	-----	29.3
6344	480	18.00	223.00	-----	
Aver.		15.42	391.80	407.22	
6347-48	0	2.19	54.21	56.40	
Net.		13.23	337.59	350.82—	
6345	960	5.52	21.60	-----	8.7
6346	960	4.56	494.20	-----	
Aver.		5.04	258.00	263.04	
6347-48	0	2.19	54.21	56.40	
Net.		2.85	203.79	206.64—	
6347	0	3.18	53.22	-----	56.40
6348	0	1.20	55.20	-----	
Aver.		2.19	54.21	56.40	
(1) 6343	Duplicate	-----	556.80	-----	
(2) 6344	do.	-----	211.2	-----	
(3) 6345	do.	-----	31.2	-----	
(4) 6346	do.	-----	465.6	-----	

EXPERIMENT 463.

Lab. No.	Mgs. N. as Am. S.	Parts N. per Million Parts Soil as:			
		NO ₂	NO ₃	NO ₂ & NO ₃	Net. NO ₂ & NO ₃
7729	-----	0.9—	4.0	-----	-----
7730	-----	0.9—	4.0	-----	-----
Aver.	0 Mgs. N. as Am. S.	0.9—	4.0	4.9—	-----
7715	-----	0.9—	9.4	-----	-----
7716	-----	0.9—	8.8	-----	-----
Aver.	2 Mgs. N. as Am. S.	0.9—	9.2	10.1—	-----
7729-30	Nitrification	-----	-----	4.9—	5.2
7717	-----	0.9—	4.0	-----	-----
7718	-----	0.9—	4.6	-----	-----
Aver.	20 Mgs. N. as Am. S.	0.9—	4.3	5.2—	-----
7729-30	Nitrification	-----	-----	4.9—	0.3
7719	-----	0.9—	11.0	-----	-----
7720	-----	0.9—	11.0	-----	-----
Aver.	60 Mgs. N. as Am. S.	0.9—	11.0	11.9—	-----
7729-30	Nitrification	-----	-----	4.9—	7.0
7721	-----	0.9—	22.0	-----	-----
7722	-----	Not received.	-----	-----	-----
Aver.	120 Mgs. N. as Am. S.	0.9—	22.0	22.9—	-----
7729-30	Nitrification	-----	-----	4.9—	18.0
7723	-----	0.9—	9.4	-----	-----
7724	-----	0.9—	8.5	-----	-----
Aver.	240 Mgs. N. as Am. S.	0.9—	8.9	9.8—	-----
7729-30	Nitrification	-----	-----	4.9—	4.9
7725	-----	0.9—	4.0	-----	-----
7726	-----	0.9—	2.6	-----	-----
Aver.	480 Mgs. N. as Am. S.	0.9—	3.3	4.2—	-----
7729-30	Nitrification	-----	-----	4.9—	-0.7
7727	-----	0.9—	3.3	-----	-----
7728	-----	0.9—	3.3	-----	-----
Aver.	960 Mgs. N. as Am. S.	0.9—	3.3	4.2—	-----
7729-30	Nitrification	-----	-----	4.9—	-0.7

In experiment 352 the greatest nitrification was when ammoniacal nitrogen was added to 400 grms. of soil to the amount of 240 milligrams at the beginning. This is equivalent to 600 parts per million of soil. 480 milligrams of ammoniacal nitrogen gave the next greatest nitrification and 120 milligrams next. But the greatest nitrification based

upon per cent of initial added nitrogen was when 120 milligrams nitrogen were added at the beginning. This corresponds to 300 parts of added nitrogen per million parts of soil or 300 milligrams to 1 kilogram.

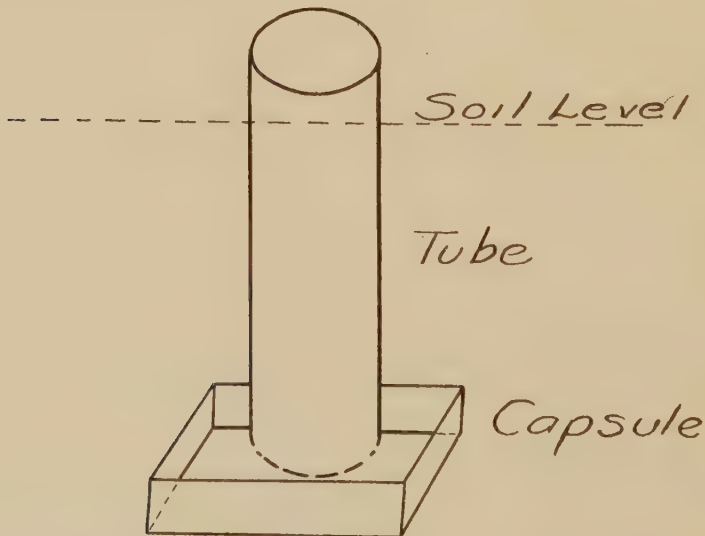
In experiment 463 the nitrification was small in all cases, but was greatest when there was 120 milligrams of added initial nitrogen. The percentages were small in each case.

The two experiments together would indicate 120 milligrams of nitrogen as the preferable amount in the soils used.

TO DETERMINE THE RELATIVE N. E. OF SOILS AS MEASURED BY TESTS IN FLASKS IN THE INCUBATOR ROOM; IN FLASKS BURIED IN THE SOIL IN THE FIELD, AND IN TUBES SIMILARLY BURIED.

Experiment 374. May, 1910.

The soil samples were made up in the usual way. One set of flasks, however, was buried in the plats, being set in the ground so deeply that only a few centimeters of the neck protruded. The tubes used were of special construction of heavy annealed glass 18 cm. long, 6 cm. in diameter, the bottom being perforated by holes, each 2 mm. in diameter. These tubes were set in glass capsules of appropriate size so as to catch any drainage water that might percolate through. This water was included in the analyses.



Both the buried tubes and buried flasks were protected from rain by glass covers.

Two soils were tested thus, every determination being made in duplicate.

TABLE IX.—EXPERIMENT 374.
RELATIVE N. E. OF SOILS BY VARIOUS METHODS.

Lab. No.				Per Cent. N as:			
				NO ₂	NO ₃	NO ₂ and NO ₃	
6797	Sterile 1931 and 240 mgs. N. as Am. S. Incubated flask.			0.4	79.2	-----	70.3
6798	" 240 " "			0.1—	78.6	-----	
Aver.				0.3	78.9	79.2—	
6795	" 0 " "			0.1—	8.8	-----	
6796	" 0 " "			Not	rec'd.	-----	
Aver.				0.1—	8.8	8.9—	
Net N.E.	(Incubated flask)						
6801	1931 and 240 mgs. N. as Am. S. Buried flask.			0.7	20.6	-----	18.1
6802	" 240 " "			0.8	21.1	-----	
Aver.				0.8	20.9	21.77—	
6799	" 0 " "			0.6	3.2	-----	
6800	" 0 " "			0.3	3.0	-----	
Aver.				0.5	3.1—	3.6—	
Net N.E.	(Buried flask)						
6805	1931 and 240 mgs. N. as Am. S. Buried tube.			0.9	18.5	-----	16.4
6806	" 240 " "			0.9	14.5	-----	
Aver.				0.9	16.5	17.4—	
6803	" 0 " "			-----	-----	1.0—	
6804	" 0 " "			-----	-----	1.0—	
Aver.				-----	-----	1.0—	
Net N.E.	(Buried tube)						
6809	Soil plat 4 and 240 mgs. N. as Am. S. Incubated flask.			0.0	37.0	-----	32.5
6810	" 240 " "			0.0	34.5	-----	
Aver.				0.0	35.8	35.8—	
6807	" 0 " "			0.1—	3.0	-----	
6808	" 0 " "			0.4	3.0	-----	
Aver.				0.3—	3.0—	3.3—	
Net N.E.	(Incubated flask)						
6813	Soil plat 4 and 240 mgs. N. as Am. S. Buried flask.			0.1—	21.9	-----	23.8
6814	" 240 " "			0.0	27.5	-----	
Aver.				0.1—	24.7	24.8—	
6811	" 0 " "			-----	-----	1.0—	
6812	" 0 " "			-----	-----	1.0—	
Aver.				-----	-----	1.0—	
Net N.E.	(Buried flask)						
6817	Soil plat 4 and 240 mgs. N. as Am. S. Buried flask.			0.0	16.6	-----	16.8
6818	" 240 " "			0.0	15.0	-----	
Aver.				0.0	15.8	15.8—	
6813	" 0 " "			-----	-----	1.0—	
6816	" 0 " "			-----	-----	1.0—	
Aver.				-----	-----	1.0—	
Net N.E.	(Buried tube)						

It is seen that the incubation room flasks gave a much higher N. E. than the buried flasks, and similarly that the N. E. as shown in the buried flasks was somewhat higher than in the buried tubes. This conclusion

is the same whether we regard the net N. E. or the nitrate nitrogen formed from the nitrogenous material originally present in the soil or the total nitrate formed in the cultures at the end of the experiment. It appears, moreover, that the temperature of the incubation room caused greater acceleration of nitrification in the case of soil 1931 than it did in the case of soil from plat 4, as shown by the ratio 70:32 though when tested by the buried tube method the N. E. is found to be practically equal in the two soils.

These facts are interesting since they show that even the change of the condition from the field to the incubation room may cause two soils of apparently equal field nitrifying power to show large differences in laboratory nitrifying power.

From such facts it becomes obvious that soil tests in order to give us knowledge of the phenomena as they occur in the field must be made under conditions of the field.

TO STUDY THE EFFECT OF ADDING LIME, COW MANURE AND A VIGOROUS NITRIFYING SOIL TO SOIL 1931 IN VARIOUS PROPORTIONS.

Experiment 357, Parts 1, 2, 3, 4, and 5. December 20, 1909, to April 11, 1910.

Plats .0001 of an acre in the experiment ground were employed. Also one plat indoors made on the concrete floor in the basement of the agricultural building.

To make the outdoor plats, pits were dug in a still impervious red clay soil (Cecil clay) and board boxes without bottoms, inside dimensions 26x24x8 inches were set in these pits, the edges projecting a few inches above the surrounding soil. Red clay was tightly tamped around these frames and in the bottom so that the pits could receive the experimental soil to a depth of about six inches, and with an area of .0001 acre (4 sq. ft.).

The soils for the several plats were prepared as follows:

In each case where soil 1931 is referred to it was sifted through a 5 mesh screen to remove stones and roots, etc., and was then mixed thoroughly.

Plat 1 consisted of soil 1931 with lime (CaO) added at the rate of 1000 pounds per acre, or approximately 40 gms. per plat.

Plat 2 was the same as Plat 1, except that cow manure was added at the rate of 20 tons per acre, or 4 pounds per plat. This was as taken from barn.

Plat 3 was identical with Plat 2, except that a vigorously nitrifying soil (Georgia soil No. 1) was added at the rate of 300 pounds per acre.

Plat 4 was like Plat 3, except that Georgia soil No. 1 was added at the rate of 5 tons per acre.

Plat 5. This plat was made 2'10"x6'4" in size on the concrete floor in the basement of the agricultural building by running in board boundaries 8.5" high. The soil placed in this area to a depth of 7 inches consisted of soil 1931 with cow manure and Georgia soil No. 1 and lime thoroughly mixed.

Determinations of N. E. were made in the usual way¹ in each plat at the beginning and subsequent determinations at the end of two weeks, one, two, and three months.

One error unavoidable in such work is that incident to imperfect sampling, an error likely to be appreciable, especially in the plats bearing the cow manure. Some slight discrepancies in the results are doubtless attributable to this cause. The details of the results are presented in Table X and a summary is found in Table XI.

TABLE X.—EXPERIMENT 357. Showing effect on N. E. of adding various substances 400 grams live soil No. 1931.

PART 1—Mixture standing no weeks.

Lab. No.	Plat No.	Mgs. N. as Am. S.	Percentage of Initial Added N. Recovered as:			N. E.
			NO ₂	NO ₃	NO ₂ and NO ₃	
6350	1	240	0.2—	1.0—	-----	0.0
6351	1	240	0.2—	1.0—	-----	
Aver.	1		0.2—	1.0—	1.2—	
6352	1	0	0.2—	1.0—	-----	
6353	1	0	0.2—	1.0—	-----	
Aver.	1		0.2—	1.0—	1.2—	
Net N. E.		(Lime)	-----	-----	-----	0.0
6354	2	240	0.2—	1.0—	-----	1.2—
6355	2	240	0.2—	1.0—	-----	
Aver.	2		0.2—	1.0—	1.2—	
6356	2	0	0.0	0.0	-----	
6357	2	0	0.0	0.0	-----	
Aver.	2		0.0	0.0	0.0	
Net N. E.		(Lime and cow manure)	-----	-----	-----	1.2—
6358	3	240	0.2—	1.0—	-----	0.0
6359	3	240	0.2—	1.0—	-----	
Aver.	3		0.2—	1.0—	1.2—	
6360	3	0	0.2—	1.0—	-----	
6361	3	0	Not rec'd.		-----	
Aver.	3		0.2—	1.0—	1.2—	
Net N. E.		(Lime, cow manure and inoculated by Georgia soil No. 1)-----	-----	-----	-----	0.0
6362	4	240	0.2—	1.0—	-----	0.0
6363	4	240	0.2—	1.0—	-----	
Aver.	4		0.2—	1.0—	1.2—	
6364	4	0	0.2—	1.0—	-----	
6365	4	0	0.2—	1.0—	-----	
Aver.	4		0.2—	1.0—	1.2—	
Net N. E.		(Lime, cow manure and inoculated by Georgia soil No. 1)-----	-----	-----	-----	0.0
6366	5	240	0.2—	1.0	-----	1.2—
6367	5	240	0.2—	1.0	-----	
Aver.	5		0.2—	1.0	1.2—	
6368	5	0	0.0	0.0	-----	
6369	5	0	0.0	0.0	-----	
Aver.	5		0.0	0.0	0.0	
Net N. E.		(Indoor plat)-----	-----	-----	-----	1.2—

¹Stevens, F. L., and Withers, W. A., Cent. f. Bak., II Abt. Bd. 34, 187-203.

TABLE X—Continued.

PART 2.—Mixtures standing 2 weeks.

Lab. No.	Plat No.	Mgs. N. as. Am. S.	Percentage of Initial Added N. Recovered as:			N. E.
			NO ₂	NO ₃	NO ₂ and NO ₃	
6376	1	240	0.2—	18.07	-----	13.7
6377	1	240	0.2—	15.4	-----	
Aver.	1		0.2—	16.7	16.9—	
6378	1	0	0.2—	3.0—	-----	
6379	1	0	0.2—	3.0—	-----	
Aver.	1		0.2—	3.0—	3.2	
Net N. E.	(Lime)	-----	-----	-----	-----	13.7
6380	2	240	0.2—	16.1	-----	12.2
6381	2	240	0.2—	14.2	-----	
Aver.	2		0.2—	15.2	15.4	
6382	2	0	0.2—	3.0—	-----	
6383	2	0	0.2—	3.0—	-----	
Aver.	2		0.2—	3.0—	3.2—	
Net N. E.	(Lime and manure)	-----	-----	-----	-----	12.2
6384	3	240	0.2—	11.1	-----	-6.3*
6385	3	240	0.2—	12.3	-----	
Aver.	3		0.2—	—11.7	11.9	
6386	3	0	0.2—	16.7	-----	
6387	3	0	0.2—	19.2	-----	
Aver.	3		0.2—	18.0	18.2	
Net N. E.	(Lime, manure and Georgia soil, No. 1)	-----	-----	-----	-----	-6.3*
6388	4	240	0.2—	35.8	-----	29.9
6389	4	240	0.2—	36.8	-----	
Aver.	4		0.2—	36.3	36.5	
6390	4	0	0.2—	7.3	-----	
6391	4	0	0.2—	3.4	-----	
Aver.	4		0.2—	6.4	6.6	
Net N. E.	(Lime, manure and Georgia soil No. 1)	-----	-----	-----	-----	29.9
6392	5	240	0.2—	80.6	-----	18.5
6393	5	240	0.2—	83.7	-----	
Aver.	5		0.2—	82.2	82.4	
6394	5	0	0.2—	64.3	-----	
6395	5	0	0.2—	63.1	-----	
Aver.	5		0.2—	63.7	63.9	
Net N. E.	(Indoor plat)	-----	-----	-----	-----	18.5

*This indicates imperfect sampling.

TABLE X—Continued.

PART 3.—Mixtures standing 4 weeks.

Lab. No.	Plat No.	Mgs. N. as Am. S.	Percentage of Total Added N. Recovered as:			N. E.
			NO	NO ₂	NO ₂ and NO ₃	
6497	1	240	0.1—	*4.1	-----	0.7—
6498	1	240	0.0	3.0—	-----	
Aver.	1		0.1—	3.6—	3.7—	
6499	1	0	0.0	3.0—	-----	
6500	1	0	Not rec'd.			
Aver.	1		0.0	3.0—	3.0	
Net N. E.	(Lime)	-----	-----	-----	-----	
6501	2	240	0.1—	18.8	-----	18.8
6502	2	240	0.1—	23.8	-----	
Aver.	2		0.1—	20.8	20.8	
6503	2	0	0.0	3.0—	-----	
6504	2	0	0.0	1.0—	-----	
Aver.	2		0.0	2.0—	2.0—	
Net N. E.	(Lime and manure)	-----	-----	-----	-----	
6505	3	240	0.1—	†13.2	-----	8.4
6506	3	240	0.1—	† 5.6	-----	
Aver.	3		0.1—	9.4	9.4	
6507	3	0	0.0	1.0—	-----	
6508	3	0	0.0	1.0—	-----	
Aver.	3		0.0	1.0—	1.0—	
Net N. E.	(Lime, manure and Georgia soil No. 1)	-----	-----	-----	-----	
6509	4	240	0.1—	38.5	-----	32.9
6510	4	240	0.1—	32.2	-----	
Aver.	4		0.1—	35.9	35.9	
6511	4	0	0.0	3.0—	-----	
6512	4	0	0.0	3.0—	-----	
Aver.	4		0.0	3.0—	3.0—	
Net N. E.	(Lime, manure and Georgia soil No. 1)	-----	-----	-----	-----	
6513	5	240	0.3	95.2	-----	10.8
6514	5	240	0.3	105.2	-----	
Aver.	5		0.3	100.2	100.5	
6515	5	0	0.1—	90.2	-----	
6516	5	0	0.1—	88.9	-----	
Aver.	5		0.1—	89.6	89.7	
Net N. E.	(Indoor plat)	-----	-----	-----	-----	

Duplicates *14.7 discarded.

Duplicates †11.6 discarded.

Duplicates ‡ 9.4 discarded.

TABLE X—Continued.

PART 4.—Mixtures standing 8 weeks.

Lab. No.	Plat No.	Mgs. N. as Am. S.	Percentage of Initial Added N. Recovered as:			N. E.
			NO ₂	NO ₃	NO ₂ and NO ₃	
6691	1	240	0.1—	19.4	21.0	17.9—
6692	1	240	0.1—	21.3	-----	
Aver.	1		0.1—	20.9	-----	
6693	1	0	0.1—	3.0—	-----	
6694	1	0	0.1—	3.0—	-----	
Aver.	1		0.1—	3.0—	3.1—	
Net N. E.	(Lime)	-----	-----	-----	-----	
6695	2	240	0.1—	35.1	-----	23.7
6696	2	240	0.1—	32.0	-----	
Aver.	2		0.1—	33.6	33.6	
6697(a)	2	0	0.0	18.5	-----	
6698(b)	2	0	0.1—	1.0—	-----	
Aver.	2		0.1—	9.8	9.9	
Net N. E.	(Lime and manure)	-----	-----	-----	-----	
6699	3	240	0.1—	24.4	-----	23.5+
6700	3	240	0.1—	28.8	-----	
Aver.	3		0.1—	26.6	26.6	
6701	3	0	0.1—	3.0—	-----	
6702	3	0	0.1—	3.0—	-----	
Aver.	3		0.1—	3.0—	3.1—	
Net N. E.	(Lime, manure and Georgia soil No. 1)	-----	-----	-----	-----	
6703	4	240	0.1—	24.7	-----	23.7+
6704	4	240	0.0	26.9	-----	
Aver.	4		0.1—	25.8	25.8	
6705	4	0	0.1—	3.0	-----	
6706	4	0	0.1—	1.0—	-----	
Aver.	4		0.1—	2.0—	2.1—	
Net N. E.	(Lime, manure and Georgia soil No. 1)	-----	-----	-----	-----	
6707	5	240	0.1—	99.0	-----	16.9+
6708	5	240	0.1—	95.5	-----	
Aver.	5		0.1—	97.3	97.3	
6709	5	0	0.1—	79.6	-----	
6710	5	0	0.1—	81.1	-----	
Aver.	5		0.1—	80.4	80.4—	
Net N. E.	(Indoor plat)	-----	-----	-----	-----	

6697(a).—Duplicate

19.7.

6698(b).—Duplicate by Tiemann-Schulze

1.0—.

TABLE X—Continued.

PART 5.—Mixtures standing 12 weeks.

Lab. No.	Plat No.	Mgs. N. as Am. S.	Percentage of Initial Added N. Recovered as:			N. E.
			NO ₂	NO ₃	NO ₂ and NO ₃	
6819	1	240	0.1	17.5	-----	17.1+
6820	1	240	0.1—	22.5	-----	
Aver.	1		0.1—	20.0	20.1	
6821	1	0	-----	3.0—	-----	
6822	1	0	-----	3.0—	-----	
Aver.	1		-----	3.0—	3.0—	
Net N. E.	(Lime)	-----	-----	-----	-----	
6823	2	240	0.1—	45.7	-----	32.0—
6824	2	240	0.1—	48.9	-----	
Aver.	2		0.1—	47.3	47.4	
6825	2	0	0.0	15.0	-----	
6826	2	0	0.0	15.7	-----	
Aver.	2		0.0	15.4	15.4	
Net N. E.	(Lime and manure)	-----	-----	-----	-----	
6827	3	240	0.0	25.7	-----	23.7+
6828	3	240	0.0	27.7	-----	
Aver.	3		0.0	26.7	26.7	
6829	3	0	-----	3.0—	-----	
6830	3	0	-----	3.0—	-----	
Aver.	3		-----	3.0—	3.0—	
Net N. E.	(Lime, manure and Georgia soil No. 1)	-----	-----	-----	-----	
6809	4	240	0.0	37.0	-----	32.5+
6810	4	240	0.0	34.5	-----	
Aver.	4		0.0	35.8	35.8	
6807	4	0	0.1—	3.0—	-----	
6808	4	0	0.4	3.0—	-----	
Aver.	4		0.3—	3.0—	3.3—	
Net N. E.	(Lime, manure and Georgia soil No. 1)	-----	-----	-----	-----	
6831	5	240	0.0	99.0	-----	30.6
6832	5	240	0.0	104.9	-----	
Aver.	5		0.0	102.0	102.0	
6833	5	0	0.0	70.8	-----	
6834	5	0	0.0	72.0	-----	
Aver.	5		0.0	71.4	71.4	
Net N. E.	(Indoor plat)	-----	-----	-----	-----	

The results are summarized in Table XI.

TABLE XI.—EXPERIMENT 357. Summary of table X showing the effect on N.E. of the addition of various substances.

Nitrification—summary of Table X.

Date.		Plat 1. Lime Added.	Plat 2. Lime and Cow Manure Added.	Plat 3. Lime, Cow Manure and Georgia Soil No. 1, 300 Lbs. Per Acre.	Plat 4. Lime, Cow Manure and Georgia Soil No. 1, 5 T. Per Acre.	Plat 5. Indoors, Lime, Cow Manure and Georgia Soil No. 1.
Dec. 20, 1909	Total.....	1.2—	1.2—	1.2—	1.2—	1.2—
	Control.....	1.2—	0.0—	1.2—	1.2—	0.0—
	Net N. E.	0.0	1.2	0.0	0.0	1.2
Jan. 3, 1910	Total.....	16.9	15.4	11.9	36.5	82.4
	Control.....	3.2	3.2	18.2*	6.6	63.9
	Net N. E.	13.7	12.2	6.3*	29.9	18.5
Feb. 14, 1910	Total.....	3.7—	20.8	9.4	35.9	100.5
	Control.....	3.0—	2.0	1.0	3.0	89.7
	Net N. E.	0.7	18.8	8.4	32.9	10.8
March, 14 1910	Total.....	21.0	33.6	26.6	25.8	97.3
	Control.....	3.1—	9.9	3.1—	2.1—	80.4—
	Net N. E.	17.9+	23.7	23.5+	23.7+	16.9+
April 14, 1910	Total.....	20.1	47.4	26.7	35.8	102.0
	Control.....	3.0—	15.4	3.0—	3.3—	71.4
	Net N. E.	17.1+	32.0—	23.7+	32.5+	30.6

*Imperfect mixing.

All controls in Plats 1, 2, 3, and 4 agree in the main except the two weeks control in Plat 3 and the twelve weeks control in Plat 2. These exceptions are probably due to imperfect sampling leading to an excess of cow manure in the sample.

The controls in Plat 5 show the effect of the addition of large amounts of cow manure. They also show that the nitrates increase in this plat until the end of the first month and then gradually decrease. Even in this period 62.7 represents the nitrification of the first two weeks, and 25.8 the additional nitrification of the second two weeks.

Regarded from the amount of total nitrates present with the exception of two weeks Plats 2 and 3, the series with cow manure present, showed greater nitrification than when it was not present—usually much greater.

The addition to the lime manure plats of Georgia soil No. 1, in quantities corresponding to 300 pounds per acre, did not appreciably increase nitrification—indeed it lowered it and in some cases appreciably so. When added at the rate of five tons to the acre there was a marked increase in two cases and a decrease in two cases, leaving a doubt as to whether its effect in this amount was helpful or harmful.

REPORT OF WORK UNDERTAKEN AND ACCOMPLISHED

From About June 20, 1910, to November, 1911, on

CORN-BILL BUG. *Sphenophorus Callosus*.

BY

R. I. SMITH.

A biological study of *Sphenophorus callosus* and other injurious species of *Sphenophorus* occurring in North Carolina, was undertaken as an Adams Fund Project after being submitted for approval August 27, 1910, before which date a little preliminary study of the conditions had been made in Robeson and Columbus counties. This report covers all work that the writer has undertaken, most of which is complete so far as one year's work would admit.

A preliminary report to July 1, 1911, was furnished for the thirty-fourth annual report of the Station. That report was written while the life history studies of the bill-bug were in progress, so that considerable work done during May and June could not be recorded except in a very general manner. Now, with the season's work brought to a close a full report for the season of 1911, since the bill-bugs first became active, is given in detail form.

The report shows that during the past spring, summer and fall, a complete life history record of the bill-bug has been secured. A close study of the different stages of the insects themselves has not been made, owing to the large amount of time required to follow the breeding work and securing such field observations as were necessary to prove that the results secured by breeding bill-bugs in confinement were practically comparable with field conditions.

PRELIMINARY INVESTIGATION AND REASONS FOR UNDERTAKING THIS PROJECT.

During the spring of 1910, corn bill-bugs were reported as doing unusual damage in Camden and other coastal counties. At the suggestion of Director C. B. Williams the writer prepared to investigate the conditions in view of undertaking this work.

A field trip to Columbus and Robeson counties was made by the writer on June 20, 1910. The first serious bill-bug injury discovered was at Braswell, Columbus County, on the farm of F. T. Shepherd. On June 21 a corn field was visited in which the third planting of corn was being destroyed by the bill-bugs. Previous to that date the owner had collected several hundred by hand, so that only small numbers could be found on June 21. Still the injury was quite severe and the third planting was practically a failure. During this trip bill-bug injury was discovered, and specimens collected at three points in Robeson County, namely, Lumberton, Proctorville, and Elrod, where in every case the bill-bugs were laying eggs and breeding in young corn plants, a condition not previously known to exist in this State. A rice field near Chadbourn was also found in which bill-bugs were breeding in large numbers.

The specimens of adult beetles collected on this trip were taken to the laboratory at West Raleigh and kept alive on green cornstalks in which they continued to lay eggs until September 3, and probably later, but after that date they were not given much attention. During the winter until February 14 the bill-bugs were buried in soil in a large tin can kept out of doors under shelter. Occasionally on warm days one or more beetles was seen moving about on the surface. This lot consisted of seventeen on September 3, when they were left to go into winter quarters. On February 14, 1911, they were dug out and sixteen found alive. On March 1 all were dead, probably because of being disturbed during the cool weather.

The above statements represent the first work with bill-bugs, and indicate, for one thing, that the beetles have a remarkable power of living a long time under adverse conditions, a fact which has been amply demonstrated during 1911.

During July and August, 1910, bill-bugs were found breeding in the stems and roots of Elegant Nutgrass, *Cyperus flavicomus*, in several fields on the College farm at West Raleigh. During August and September many larvæ, pupæ, and adults were collected from *C. flavicomus* growing in a corn field situated in low ground on the College farm. These specimens, that is the adults, were kept in an out-door cage during the winter, where they remained buried most of the time, and some of them commenced egg-laying about May 28, 1911, and lived until the latter part of October, when they were killed because no further use could be made of them.

LIFE HISTORY AND HABITS OF SPHENOPHORUS CALLOPHUS.

First Appearance of Beetles in Spring.

The adult bill-bugs appear in the eastern counties, in what is considered the bill-bug section of North Carolina, as soon as the earliest corn is sprouting. The date varies with different seasons. Injury commences at once and continues as long as young corn plants are available as food for the beetles. On May 9, 1911, at St. Pauls, Robeson County, the bill-bugs were killing the second planting of corn in a field on Marcus Smith's place, and Mr. Smith said the beetles had been observed in injurious numbers for over two weeks. It was from this place that most of the bill-bugs for breeding work were secured. The records show that bill-bugs did not lay eggs this spring (1911) until May 20 or 21.

Eggs.

The first eggs secured this year were on May 22, from a lot of overwintered beetles collected at Braswell and Pembroke during October, 1910. It is possible that eggs were first laid on May 21, as that was Sunday and the material was not examined. On May 22 eggs were also discovered in *Cyperus* plants near West Raleigh. On May 26 Mr. Smith of St. Pauls wrote, "beetles have commenced to lay eggs in the corn plants," and as Mr. Smith had, by special arrangement, been looking daily for the eggs, this record may be taken as indicating about the date of first egg-laying in the field. As further evidence, a letter from

F. T. Shepherd of Braswell, dated May 17, states that, "bill-bugs have not commenced to lay eggs." Mr. Shepherd was also watching for earliest egg-laying in the field, at the writer's request. After May 22 the bill-bugs in confinement and in the field laid eggs quite regularly, as shown in the following egg-laying record.

Where, When, and How Eggs Are Deposited.

The eggs are placed by the female in specially prepared cavities in the stem of the food plant, usually within one or two inches of the ground, or sometimes just at the roots of the plants.

The female usually eats out a cavity in the thickened side of the outer corn blade and often consumes fifteen or twenty minutes in preparing this cavity. The narrow beak acts as a wedge to pierce the outer tissue, which practically closes when the beak is withdrawn. She then thrusts her ovipositer into the hole and places an egg entirely out of sight. The tissue of the leaf is forced apart by the ovipositer and the opening closes again almost completely when it is withdrawn. In very young corn plants the egg is placed in the same manner in the soft stem just above the roots. In larger corn the egg is imbedded in the outer blade and often can not be seen from either the inner or outer side. In *Cyperus* plants with thinner blades the eggs are usually found just underneath the outside blade and often two or three inches above ground.

After placing an egg the female always spends a few minutes scraping the tissue above the egg-cavity with her sharp ovipositer, evidently endeavoring to completely close up the opening.

While securing the daily egg-laying record several broken eggs were found, but the reason for it was not discovered. It is possible that the males may attempt to eat the eggs or possible that some are crushed while being deposited.

Eggs are evidently deposited in all plants on which the beetles feed. Eggs have been found in all the food plants listed on another page.

Number of Eggs Laid by Females.

The individual record of twenty-four females, in the following table, gives complete data of egg laying for the entire season of 1911. Most of the beetles secured for this record were collected at St. Pauls by Mr. Marcus Smith on May 25, and received on May 26, and were isolated as soon as mated pairs could be secured. The record, therefore, was commenced, except Nos. 1, 16, 18 and 24, about six days after the first eggs were discovered in the field. For this reason the record may lack five or six days' egg-laying, but with that exception it is complete.

Each pair was kept in a half pint jelly glass and given fresh food at least once a day, except when the record indicates that the eggs for two, or sometimes three days, were counted at one time. This was caused by the necessary absence of the writer, who took the notes for the entire record as shown in the table.

The pairs were kept in a wire cage under as near normal conditions as possible. The jelly glasses contained no earth because its presence

would have interfered with securing every egg. On many occasions one or more eggs were found loose in the glass, even though the food supplied was in fresh condition. No doubt loose eggs are deposited occasionally around plants in the field.

Food was supplied in the form of a short section of corn plant usually cut from within an inch or two of the roots. During June and July young corn plants entirely suitable for food were easily secured from the field, but after the middle of August it became necessary to find suckers or search for small plants. In fact the food supplied was no better at any time than the beetles could have found in the corn fields. During September it was difficult to find any corn suitable for food and the beetles were forced to lay eggs in hard corn stalks, or in portions of the green stalk of late suckers.

The daily record was generally taken between 12 m. and 2 p. m. On a few days a record was taken about 7 a. m. and after 6 p. m., but these special records do not appear in the table.

The great difference in the number of eggs laid by different females may indicate that they were not under suitable conditions, but all had the same treatment and some which laid only a few eggs lived until after the record was discontinued, and many are probably still alive in a wire cage where all the live ones were placed on October 27.

All the females whose egg record was secured were alive on October 27, except where the record states that individuals died on certain dates.

SPHENOPHORUS CALLOSUS.

Daily Egg-laying record of twenty-four females.

		Pair No.																									
1911		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
May	24		4																								
	25		1															1									
	26		1																	1						1	
	27		1																	1							
	28		3	3		5		2	5	5	1	1	5	5	4	2		1	4		5	2	4	1	4		
	29		2		4	1	5	4	2	3	1	4	2	1		3		1	3	1	2	1	2	3	2	1	
	30		2	2		1	1	1	3	2		1		4	2	1			4	6	2				1	2	
	31		4	3	1	3	4	4	†4	3	2	1		3		2	9	2	4		3	2	7	3	3		
	June	1		3	3	3	2	5	3	4	3		1	1	4	3	2	4	1	4	2	4	2	3	1	2	1
		2		4	4	3	4	7	3	4	4	1	1	4	4	1	3	3	2	2	6	3	2	9	2	4	3
3			4	4	1		3	4	3	2	3	3	3	5	2	1	3		3	2	3	1	4	1	1	1	
4			1	4	4	3	6	6	3	5		3	4	3	2		1	1	2	2	2	2	4	3	3	1	
5			1		2		4	4	1	3	2	1	2	6	1	1	4	1	5	1	1		1	3	5		
6			3	5	5		6	3	3	1		4	7	5	3	2	5	1	2	5	4		8	2	1	1	
7			2	3	1	1	6	5	*4	3	1	3	4	3	1	2	2	4	2	1		1	4	2	1		
8			1	3	2		3	4	1	2			4	5			2	1	1	3	3	2	4		3		
9			2	2			4	4	2	3		3	3	3		2	4	1	1				4	2	1		
10			1	3	3		3	3	1			2	4	3	6	2	2	4	1		5	3	1	6	3	1	
11			2	2	1	1	4	3	3	3		2	2	4		1	2		1	1	1		1	3	3		
Total		35	48	30	21	61	53	43	42	13	32	44	61	21	24	43	18	38	37	36	16	61	29	35	11		

*One broken egg included. †Two broken eggs included. ‡Three broken eggs included.

SPHENOPHORUS CALLOSUS—CONTINUED.

Daily Egg-laying record of twenty-four females.

		Pair No.																									
1911		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
June	12	4	3	3	1	9	*3	*2	2	2	†5	5	6	2	5	6	1	2	3	2	2	3	*3	*1	1		
	13	3	3	---	1	3	1	1	2	2	2	5	3	1	3	5	1	2	3	3	1	1	3	2	---		
	14	3	4	3	3	6	---	1	1	1	---	3	7	---	---	6	4	1	2	1	1	6	*4	3	---		
	15	2	3	3	---	4	5	4	1	---	2	4	2	1	1	4	1	---	2	1	---	1	2	3	---		
	16	1	4	4	2	7	6	---	2	1	*4	5	8	1	6	8	2	3	---	2	4	4	2	---			
	17	4	1	*2	2	3	2	5	2	1	4	2	7	---	2	7	---	1	5	---	---	5	3	3	---		
	18	2	3	2	---	4	4	1	2	1	1	6	1	---	---	*2	1	1	2	---	---	2	1	---	---		
	19	4	2	4	3	4	6	*4	3	3	4	4	4	---	4	*7	---	1	5	---	---	3	3	2	1		
	20	2	3	2	---	5	*5	---	2	2	3	5	4	---	2	6	2	---	2	1	1	4	---	3	1		
	21	2	2	3	2	6	*5	3	2	3	4	4	5	1	1	4	---	2	3	---	2	4	6	1	---		
	22	2	4	*2	1	5	*3	1	2	2	2	4	2	3	†5	---	---	*4	1	---	*3	2	3	---	---		
	23	2	5	3	2	*3	4	3	1	3	4	5	8	2	1	*5	---	2	4	---	*2	5	---	---	---		
	24	3	3	4	2	*5	7	2	4	3	4	5	1	3	1	10	---	1	4	---	---	1	*4	4	---		
	25	3	4	*3	1	8	3	2	3	1	2	*4	†6	1	*3	5	---	4	2	---	---	3	2	---	---		
	26	4	4	4	2	*6	7	2	3	2	3	*6	†5	2	*4	9	---	3	5	---	---	3	4	1	---		
	27	4	5	3	---	3	*8	1	1	---	1	6	9	1	3	7	---	---	5	---	---	1	2	---	---		
	28	2	6	3	3	*6	5	---	4	3	1	*3	4	1	1	5	---	*3	2	---	---	2	3	---	1		
	29	3	6	†5	---	4	4	---	3	2	---	6	6	---	3	7	---	---	2	---	---	2	2	---	---		
	30	2	4	*5	1	2	†6	2	*2	3	---	*5	*2	1	1	6	---	2	4	2	---	4	4	---	---		
July	1	2	4	6	2	4	5	---	2	2	---	2	4	1	3	†6	---	†3	---	---	---	4	5	1	1		
	2	---	5	3	1	2	7	---	*2	4	---	3	*11	---	2	5	---	*3	---	---	---	2	4	2	---		
	3	1	5	6	---	3	5	2	1	2	---	6	5	---	3	4	---	1	2	---	---	3	4	2	---		
	4	1	*4	4	---	4	5	---	5	2	---	4	4	1	2	4	---	---	1	1	---	1	---	---	---		
	5	---	*3	*2	1	4	*3	1	4	2	---	*4	6	---	2	7	---	---	2	---	---	4	5	1	---		
	6	---	6	*4	1	4	5	---	3	4	---	4	4	---	*5	5	---	1	1	---	---	3	*3	2	---		
	7	1	3	2	---	*3	*3	1	3	1	---	*7	8	---	4	---	---	---	---	---	---	3	4	1	---		
	8	1	*7	*3	---	5	2	---	5	3	---	3	*5	---	*4	4	D	---	*2	---	---	2	*8	---	---		
	9	2	5	3	---	4	5	---	2	3	---	5	5	---	4	2	---	---	1	---	---	3	4	3	2		
	10	3	4	†3	---	3	3	2	4	3	---	4	4	---	3	6	---	1	1	---	---	2	3	---	---		
Total		63	115	94	31	129	127	40	73	61	46	127	148	21	76	157	12	30	78	12	10	81	98	40	8		
July	11	1	6	3	---	1	8	---	*2	1	---	3	4	---	5	3	---	---	3	---	5	6	2	---	---		
	12	---	5	4	---	4	5	1	4	3	---	4	9	---	5	7	---	*4	1	---	3	*3	---	---	---		
	13	2	6	1	---	5	1	1	4	3	---	4	9	---	3	6	---	1	*4	---	1	1	1	---	---		
	14	*3	5	2	---	4	5	---	*2	3	---	4	4	---	4	6	---	---	5	---	2	5	1	1	---		
	15	*3	3	2	---	2	3	---	2	2	---	5	5	---	4	3	---	---	5	---	2	5	2	---	---		
	16	---	5	*3	---	4	†5	1	†4	5	---	3	*7	---	3	3	---	---	6	---	*3	*5	2	---	---		
	17	---	5	3	---	6	†4	---	3	3	---	6	6	---	2	3	---	2	1	4	---	*3	4	1	1		
	18	1	7	*4	---	3	*3	---	6	4	---	4	6	1	3	8	---	1	---	5	---	4	3	1	2		
	19	1	5	†6	---	3	4	1	4	3	---	3	*5	---	4	*3	---	---	6	---	3	4	3	---	---		
	20	---	2	†7	---	2	7	---	4	3	---	1	3	---	2	*4	---	---	4	---	2	*3	*2	2	---		
	21	1	7	†5	1	5	5	1	3	5	---	*5	*8	---	*5	4	---	---	*4	---	3	*7	1	1	---		
	22	---	4	8	---	2	†7	2	2	4	---	6	2	---	4	1	---	1	1	*5	---	3	*4	1	1		
	23	---	3	4	---	5	*4	1	3	4	---	4	†5	---	3	3	---	---	†5	---	2	7	1	1	---		
	24	1	6	5	---	3	2	1	*5	5	---	6	4	---	5	1	---	---	4	---	2	5	1	---	---		
	25	1	7	10	---	5	*10	2	2	5	---	4	7	---	5	5	---	1	*6	---	2	6	1	---	---		
	26	---	1	3	---	1	3	1	1	3	---	5	2	---	2	---	---	---	1	3	---	4	1	1	1		
	27--28	1	7	†9	---	5	*6	2	5	6	---	9	*6	---	8	5	---	1	1	*1	---	*3	*7	2	1		
	29	---	7	*7	---	4	5	2	2	3	---	5	1	---	2	6	---	1	1	---	3	3	2	---	---		

*One broken egg included. †Two broken eggs included. ‡Three broken eggs included. D.—Died.

SPHENOPHORUS CALLOSUS—CONTINUED.

Daily Egg-laying record of twenty-four females.

1911	Pair No.																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
July 30	1	6	3		3	7	3	3	5		5	6	1	3					*2		4	*4		2
31	1	3	4		3	2	3	3	3		*3	3	5	2					2		*2	*4	4	
August 1	1	8	6		6	8	1		5		6	2		1	4				2		5	3	1	
2	1	3	2		3	4	2	2	2		3	3	1	5					1		3	3	3	1
3	1	5	*4		3	1		2	4		7		1	4					3		5	8	4	
4	1	5	7		4	*5	1		4		6			2	2				3		2	3	3	
5		6	3		3	4	1	2	2		4		2		2				4		4	6	2	1
6	2	4	7		5	4	1		6		6				2				3		*4	4	3	
7		4	7		4	*4			2		8			5	7				4		4	4	3	
8-9-10		*11	9		*5	†10			*11		12	2	4						3		*7	10	4	
11		4	*6		*1	4			3		6		1	4	1				*4		4	3		
12		5	6		1	4			2		4		2						1		3	4	4	
Total	23	155	150	1	105	144	28	70	114	0	151	108	13	98	91	0	5	6	107	1	97	135	56	15
Aug. 13-14-15		*13	8		5	*11			4		10	2	2	6					1		6	11	4	1
16		5	2						*4		2	D							4		*4	5	1	
17		2	1			2			1			1			1						2	3	1	
18		8	3		1	3			5		3		2		D						1	4	*3	
19		3	*3		4	6			4		4		1	1					3		6	7	2	
20		5	3		1	3			3		4			1					1		5	3	2	
21																								
22		10	2		4	*6			5		5		2	3							*4	*6	*6	3
23																								
24		4	4		1	4			1		5								2		*3	3	3	
25-26		*5				7			1		*7		1	3							*4	*3	2	
27		4			2	2			*3		6										4	3	4	
28		4			1	*2			4		2										1	†3	5	1
29		4			1	5			4		6										*4	1	3	
30		5			2	5			3		2										*2	5	2	
31		5				4			3		1		1								3	3	2	
September 1-2		7	1		4	5			5		6										2	3	5	
3-4		7	7		3	4			6		6										3	*6	*5	
5		2	2		1				1		3											1		
6		5				5			2												1	1	1	
7		2							4													3		
8		3				1			2												1	2		
9		*5				1			1		4											2	2	
10-11		*7			1	3			1		2											2	*4	
12		4									2											2	2	
13		1			1						4												2	
14						1					1													
15		1				1																		
16		2	3		1	2																	1	
Total	0	123	39	0	32	84	0	0	67	0	85	2	10	14	1	0	0	0	11	0	56	81	63	5

*1 broken egg included. †2 broken eggs included. ‡3 broken eggs included.

D.—died. K.—killed.

SPHENOPHORUS CALLOSUS—CONTINUED.

Daily Egg-laying record of twenty-four females.

1911 Date.	Pair No.																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
September 17																								
18		3				1																	1	
19		1				1					1												1	
20		1			1	1			1	1														
21					D																1			
22																								
23																								
24																								
25																								
26—27		1	1			1																		
28—29						1																		
Total	0	6	1	0	1	5	0	0	1	0	2	0	0	0	0	0	0	0	0	0	1	0	2	0
From 1st page	35	48	30	21	61	53	43	42	13	32	44	61	21	24	43	18	38	37	36	16	61	29	35	11
From 2d page	63	115	94	31	129	127	40	73	61	46	127	148	21	76	157	12	30	78	12	10	81	98	40	8
From 3d page	23	155	150	1	105	144	28	70	114		151	108	13	98	91		5	6	107	1	97	135	56	15
From 4th page		123	39		32	84			67		85	2	10	14	1				11		56	81	63	5
Grand total	121	447	314	53	328	413	111	185	256	78	409	319	65	212	292	30	73	121	166	27	296	343	196	39

Total number laid by 24 females, 4,894 eggs.

Average number laid by each female, 204 eggs.

EGG LAYING RECORD FOR EACH MONTH. CONDENSED FROM ABOVE TABLE.

1911	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
May 24—31	11	15	5	10	10	11	14	13	4	7	7	13	6	8	9	5	15	9	12	5	13	7	10	4
June	76	102	83	37	144	126	63	71	44	71	122	140	34	60	148	25	50	90	35	20	102	79	53	12
July	28	146	129	6	106	139	28	95	92		131	157	4	109	116		8	22	80	2	83	128	39	16
August	6	132	83		57	108	6	6	93		119	9	21	35	19			39			90	108	69	7
To September 29		52	14		11	29			23		30										8	21	25	2
Totals for 5 months	121	447	314	53	328	413	111	185	256	78	409	319	65	212	292	30	73	121	166	27	296	343	196	39

Summarized Notes From the Above Egg Laying Record.

Average number of eggs from each female—204.

Longest egg-laying period, No. 2, May 24 to September 27.

Shortest egg-laying period for beetle that lived all the season after ceasing to lay eggs, No. 10, May 28 to June 28.

Female No. 20, which laid only 27 eggs in all, was apparently healthy and fed normally after ceasing to lay eggs.

Female No. 24, which laid only 39 eggs, but laid occasionally for a period of three months, was also apparently in a healthy condition at the end of the season.

Female No. 2, which laid the highest total, did not miss laying every

Many of the hatching records were not closer than twelve, or sometimes twenty-four hours, but they served as checks to prove that the close records were comparable with natural conditions.

All incubation records were secured in a wire covered house where temperature and moisture conditions were as near normal as possible.

In the following table is given a record of eggs of which the incubation period was secured to within less than twelve hours. Some of the records are almost exact. "Just hatching" means that the shell was cracked but the larva not free from the egg shell. "Just hatched" indicates that the larva had gotten free from the shell, but that the head of the larva had not had time to change color.

INCUBATION RECORD OF EGGS OF SPHENOPHORUS CALLOSUS.

Lot No.	Total No. of Eggs.	Date and Hour When Eggs Were Laid.	Date and Hour of Hatching.	Number of Hours Required for Hatching.		
				Min.	Max.	Aver.
3	2	May 23, 6 p. m. to 10 p. m.	May 30, 10 a. m. Just hatched.	156	160	158
5	1	May 23, 11 p. m. to May 24, 9 a. m.	May 31, 3 p. m. Just hatched.	174	184	179
6	1	May 24, 10 a. m. to 5 p. m.	June 1, 1:30 p. m. Just hatching.	188½	195½	192
10	1	May 26, 7 a. m. to 6 p. m.	June 2, 8 a. m. Just hatched.	158	169	163½
15	1	May 27, 10 a. m. to 4 p. m.	June 4, 10 a. m. Just hatching.	186	192	189
17	5	May 29, 12 m. to 4 p. m.	June 4, 11 a. m. Just hatched.	139	143	141
20	3	May 29, 12 m. to 2 p. m.	June 4, 8 p. m. to June 5, 7 a. m.	150	162	156
21	1	May 29, 1 p. m. to 2 p. m.	June 4, 11 a. m. Just hatched.	141	142	141½
25	2	June 2, 1 p. m. to 3 p. m.	June 8, 7 p. m. Just hatched.	148	150	149
29	1	June 3, 4 p. m. to 6 p. m.	June 10, 12 m. Just hatched.	162	164	163
32	1	June 5, 4 p. m. to 6 p. m.	June 12, 9 a. m. Just hatched.	159	161	160
35	1	June 5, 4 p. m. to 6 p. m.	June 14, 12 m. to 4 p. m.	210	216	213
44	3	June 9, 8 p. m. to June 10, 6 a. m.	June 15, 6 p. m. Just hatching.	132	142	137
45	7	June 10, 8 a. m. to 6 p. m.	June 16, 3 p. m. Hatched and Hatching.	141	151	146
49	6	June 17, 10 a. m. to 5 p. m.	June 23, 10 a. m. Just hatched.	137	144	140½
51	5	July 25, 1 p. m. to 5 p. m.	July 31, 12 m. to 5 p. m.	139	148	140½
55	5	Aug. 1, 1 p. m. to 5 p. m.	Aug. 6, 11 p. m. Just hatched.	126	130	138

Summary of Incubation Record, With Additional Notes.

The average incubation period for the eggs recorded in above record is practically 159 hours or a little over six and a half days.

The shortest average period is 128 hours for five eggs deposited August 1, or practically five and one-third days. These eggs hatched in a tin box with plenty of moisture and during the warmest part of summer.

The longest average period of 213 hours, or practically nine days, was secured from an egg kept in a rather dry atmosphere and was in no way due to being retarded by cool weather.

Eggs were hatched in less than five days on two occasions. The first

was a lot of thirteen eggs taken June 25, 1 p. m., and laid during the previous twenty-four hours or less. On June 29 at 1 p. m., one egg had hatched and the others hatched before night. Another lot of six eggs taken between June 26, 10 a. m. and 3 p. m., were hatching on July 1 at 9 a. m. All hatched at less than five days old.

Five days for egg-hatching should not, however, be considered as the average minimum time. During the progress of the breeding work hundreds of eggs were hatched for the purpose of securing larva for rearing and while records of all were not kept, it is safe to say that only a small per cent hatched in less than six days.

Eggs kept in a very dry atmosphere may be greatly retarded and very few will hatch unless moisture is furnished before the eggs are seven or eight days old. One lot of about 20 eggs taken June 26, 1 p. m., same being over twelve hours old, were kept very dry until July 5, when moisture was added. At that time no eggs had hatched and many were shriveled. On July 6 and 7 nine of the eggs hatched. Over 60 per cent failed to hatch. Such a condition is not liable to occur in the field, but the record proves that moisture is necessary for egg hatching.

Enemies of Eggs.

Ants have been discovered carrying *Sphenophorus* eggs into the ground. Just how much benefit they cause by destroying the eggs, the writer has not had a chance to discover. An egg dropped or placed on the ground, or exposed on the plants, is very quickly taken away by the little field ants. No other enemy of the egg has been discovered.

Larva.

The development of the larva during the warm summer months depends very largely upon its food supply. Hundreds of larvæ have been watched and a large number reared to maturity, as explained farther on, but normal development is retarded or entirely prevented by a poor food supply. Temperature conditions affect the growth of the larvæ after the latter part of August and especially so during September and October when some late hatching individuals undoubtedly occur in the field. These, however, are of minor importance since the majority of the brood must mature during August or September.

The observations and breeding work of the past season indicate clearly that the larvæ are normally present in corn and cyperus plants at all times during the summer after the first eggs hatch. A large number of these larvæ are hatched in plants too small to furnish them sufficient food for reaching mature growth. Hundreds of larvæ have been observed in cyperus plants that were too small, and the larvæ in them either died or found their way to other plants close by.

In the bill-bug sections of North Carolina which have been visited by the writer, the larvæ are readily found in all the plants on which the adults feed, namely, cyperus plants of several species, rice and corn. The writer has not found them in any of the common grasses, although other species of *Sphenophorus*, particularly the little *S. parvulus* are known to live in the roots of certain common grasses.

Method of Rearing Larvæ and Adult Beetles.

For rearing larvæ to maturity, corn stalks have been found more suitable than any other food plant. In the field the larvæ in corn plants are located near the roots, but in order to watch the development of the larvæ it was found necessary to force them to feed in the main stalk just above the roots. In all the rearing experiments recorded in these pages larvæ were placed in sections of corn stalk which were in some instances kept on moist soil, and in others, kept on top of dry soil. The latter method was found best in order to keep the larvæ from emerging and getting lost if the food did not exactly suit them.

Records of Larval Development.

The full records for the breeding experiments show that 81 specimens were reared from egg to adult stage. That is, larvæ were taken within a few hours, or within at most one day after hatching and were carefully placed in a cavity in the side of a green stalk at a point one or two inches above the root as the plant originally stood in the field. The surface of the piece of the stalk cut out to form the cavity, was always replaced and secured by a rubber band. In addition to the 81 larvæ reared to maturity, records were kept on the growth of 208 other larvae which were reared to the first, second, third or fourth molt, but failed to reach maturity either because of being killed or hurt during the times they were being examined, or because the corn stalk in which they were placed became unfit for food. In some instances the corn stalk got too dry and hard, while at other times it commenced to decay and the growth of black mould interfered with the normal growth of the larva. Some larvæ were also killed by mites, which at times interfered seriously with the experiments.

The larvæ that were reared to maturity were numbered from 1 to 81, these numbers being given after the completion of the work. It is possible that the development of some of the larvæ was retarded slightly by the almost daily examination which was necessary to determine just when the molts occurred. In the following table only the dates showing when the larvæ molted, are given, but the full records of the work show in some cases, that the larvæ were actually seen nearly every day.

The following table does not show, in every instance when the molts occurred, but the records given are very close, at least to within less than twenty-four hours, unless otherwise stated.

This table shows also the length of the pupal stage for those that emerged as mature beetles.

Nos. 1 to 63 were all reared to the mature beetle stage.

The records of Nos. 64 to 81 were not kept after the pupæ were secured.

RECORD OF DURATION OF LARVAL AND PUPAL STAGES.

No. of Record	Date of Hatching.	Date of Shedding 1st Molt.	Date of Shedding 2d Molt.	Date of Shedding 3d Molt.	Date of Shedding 4th Molt.	Date of Pupating.	Date Adult Emerged.	No. of Days Larval Stage.	No. of Days Pupal Stage.	Sex of Beetle.
1	June 3, 4-7 p. m.	?	June 23-24	?	July 13, 10 a. m. Just molted	July 21, 6 p. m.	July 30, 12 m.-	48	9	Female
2	June 4, 10-11 a. m.	?	?	?	July 1, 10 a. m. Quite recent	July 22, 9 a. m. July 8, 10 a. m.	July 31, 10 a. m. July 17, 10 a. m.	34	9	Female
3	June 3, 6 p. m.-	?	?	?	?	July 7, 5 p. m.	July 16, 11 a. m.	34	8	Male
4	June 4, 9 a. m.	June 12-13	June 25-26	July 5-6	July 11, 11 a. m.	July 8, 10 a. m.	July 28, 2-5 p. m.	40	9½	Female
5	About 7 a. m.	?	?	?	Quite recent July 3-4	July 19, 11 a. m.	July 22, 10 a. m.-	35	8½	Female
6	June 8	June 12-13	June 19-20	?	July 1, 11 a. m.	July 14, 9 a. m.	4 p. m.	32	9	Male
7	About 7 p. m.	?	?	?	Just molted ?	July 10, 7 p. m.	July 20, 9 a. m.	29½	9	Male
8	June 9	June 15-16	?	?	July 1, 9 a. m.	July 8, 7 p. m.	July 17, 1 p. m.	27½	8	Female
9	10 a. m.-4 p. m.	June 14-15	June 19-20	June 23-24	June 30	July 6, 6 p. m.	July 14, 11 a. m.	26½	8	Male
10	10 a. m.-4 p. m.	June 15	?	July 10-11	July 1	July 7, 9 a. m.	July 15, 10 a. m.	44	9	Female
11	12 m.-6 p. m.	About 12 m.	?	June 23-24	July 15-16	July 5, 5 p. m.	July 13, 12 m.	33	9½	Female
12	At 11 a. m.	June 14-15	June 23-24	June 27-28	July 2-3	July 6, 11 a. m.	Aug. 3, 9 a. m.	36	8½	Male
13	June 9, 5-6 p. m.	June 14-15	June 23-24	June 27-28	July 5-6	10 a. m.-1 p. m.	Emerging	30	9	Female
14	June 10, 11 a. m.	June 15-16	June 19-20	?	July 1, 10 a. m.	July 12, 6 p. m.	July 22, 4 p. m.	30	9	Female
15	June 11, 12 m.	?	?	?	Just molted	July 13, 9 a. m.	Emerging	38	9	Male
16	June 9, 6 p. m.-	June 15-16	June 27-28	July 2-3	July 10	July 15, 2 p. m.	July 24, 9 a. m.	30	9	Female
	June 10, 6 a. m.	?	?	?	July 2-3	July 16, 11 a. m.	Just adult	30	9	Female
	June 10-11	?	?	?	July 5-6	July 9, 7 p. m.	July 18, 10 a. m.	38	9	Male
	June 10, 7 p. m.-	?	June 22, 10 a. m.	June 27-28	July 5-6	10 a. m.-6 p. m.	July 20, 9 a. m.	35½	9½	Male
	June 11, 9 a. m.	June 19-20	Just molted	July 2-3	July 10-11	July 18, 7 p. m.	July 27, 6 p. m.			
	June 13	June 19-20	June 27-28	July 2-3	July 10-11	July 19, 10 a. m.	July 28, 9 a. m.			
	9 a. m.-2 p. m.					July 18, 10 a. m.	July 28, 9 a. m.			
						July 19, 10 a. m.	Emerging			

RECORD OF DURATION OF LARVAL AND PUPAL STAGES—Continued.

Record No.	Date of Hatching.	Date of Shedding 1st Molt.	Date of Shedding 2d Molt.	Date of Shedding 3d Molt.	Date of Shedding 4th Molt.	Date of Pupating.	Date Adult Emerged.	No. of Days Larval Stage.	No. of Days Pupal Stage.	Sex of Bee.
17	June 13 9 a. m.-2 p. m.	?	?	?	?	July 19, 6 p. m.	July 29, 12 m.	36½	9½	Female
18	June 13, 4-6 p. m.	?	June 23-24	June 28-29	July 7-8	July 20, 9 a. m.	Emerging	33	9½	Male
19	June 15, 6 p. m.	June 19-20	June 25-26	July 2-3	July 5-6	July 17, 10 a. m.	Emerging	30	8½	Female
20	June 15, 10 a. m.	June 21-22	June 25-26	?	July 5-6	10 a. m.-1 p. m.	July 23, 6 p. m.- July 24, 9 a. m.	26½	9½	Female
21	June 15, 7 p. m.- June 16, 9 a. m.	June 21-22	June 25-26	July 2-3	?	July 11, 10 a. m.- July 12, 9 a. m.	Emerging	28	9	Male
22	June 15, 7 p. m.- June 16, 9 a. m.	June 19-20	June 23-24	June 27-28	July 10-11	July 12, 9 a. m.	July 20, 4 p. m.- July 21, 9 a. m.	32½	8½	Female
23	June 15, 6 p. m.- June 16, 9 a. m.	June 26-27	July 1	?	July 13, 9 a. m.	Just pupated	July 27, 9 a. m.	40½	9½	Female
24	June 21, 6 p. m.- June 22, 9 a. m.	June 25-26	June 29-30	July 4-5	Just molted	Just pupated	Aug. 4, 7 p. m.- Aug. 5, 9 a. m.	26	8	Female
25	June 21, 6 p. m.- June 22, 9 a. m.	?	July 4-5	?	July 11, 12 a. m.	July 17, 4 p. m.- July 18, 9 a. m.	July 25, 6 p. m.- July 26, 10 a. m.	47	8½	Female
26	June 21, 6 p. m.- June 22, 9 a. m.	June 28-29	?	?	July 26, 10 a. m.	Aug. 7, 2 p. m.	Aug. 15, 6 p. m.	30½	9	Female
27	June 22	June 28-29	July 2-3	July 11-12	Just molted	Just pupated	Just emerged	42	8½	Female
28	June 26, 11 a. m.	June 29-30	June 29-30	?	July 19-20	10 a. m.-4 p. m.	Just emerged	46	8½	Female
29	June 22	Just molted	July 4-5	July 10-11	July 15-16	Just pupated	Aug. 7, 9 a. m.	32½	10	Female
30	June 21-22	June 28-29	July 2-3	July 6-7	July 15-16	July 24, 6 p. m.- July 25, 9 a. m.	Emerging	29	10	Female
31	June 21-22	June 27-28	July 2-3	July 6-7	July 16-17	July 20, 6 p. m.- July 21, 9 a. m.	Quite recent	33½	10	Female
32	June 22, 6 p. m.- June 23, 9 a. m.	June 26-27	July 1	July 5-6	?	July 25	Aug. 4, 3:30 p. m.	30½	9	Female
						10 a. m.-6 p. m.	Just emerging			
						July 22	July 31, 1 p. m.			
						11 a. m.-4 p. m.	Just adult			

33	June 23 11 a. m.-4 p. m.	June 28, 10 a. m. Just molted	July 2-3	July 5-6	July 18, 11 a. m.	July 28, 10 a. m.- July 29, 9 a. m.	Aug. 7, 9 a. m. Recent	35½	9	Male
34	June 22, 6 p. m.- June 23, 8 a. m.	June 27, 11 a. m.	June 30, 4 p. m.	?	July 11-12	July 18, 7 p. m.- July 29, 9 a. m.	July 28, 6 p. m.- Aug. 2, 7 p. m.- Aug. 3, 9 a. m.	26	10	Female
35	June 23	June 27-28	?	July 10-11	July 16-17	July 23, 11 a. m.- July 24, 9 a. m.	Aug. 2, 7 p. m.- Aug. 3, 9 a. m.	30½	9	Female
*36	June 24, 10 a. m.	June 28-29	July 3, 3 p. m.	July 6-7	July 14-15	Aug. 16, 12 m.- Aug. 17, 9 a. m.	Aug. 26, 11 a. m.	53½	9½	Male
37	June 26, 2-3 p. m.	?	Just molted July 5, 11 a. m.	July 10-11	July 14-15	July 24, 6 p. m.- July 25, 9 a. m.	Aug. 3, 2 p. m. Just adult	38	9½	Male
38	June 26, 3-4 p. m.	July 1, 1 p. m. Just molted	Just molted July 5-6	July 11, 12 m. Just molted	July 16-17	Aug. 1, 9 a. m.	Aug. 10, 10 a. m.	36	9	Male
39	June 27, 2-3 p. m.	July 2-3	July 5-6	July 10-11	July 17-18	July 25, 12 m.- July 26, 10 a. m.	Aug. 4, 10 a. m. Recent	28½	10	Male
40	June 27, 2:30 p. m.	?	July 5-6	July 10-11	July 16-17	July 24, 6 p. m.- July 25, 9 a. m.	Aug. 3, 2 p. m. Just emerged	27½	10	Male
41	June 27, 11:30 a. m.	July 3, 3 p. m. Recent	?	?	?	Aug. 3, 10 a. m.	Aug. 12, 9 a. m.	37	9	Male
42	June 27 1-2 p. m.	?	?	?	?	Very recent July 30, 11 a. m.-	Emerging Aug. 9-10	33½	?	Male
43	June 28, 1-4 p. m.	?	?	?	?	July 31, 9 a. m. July 25, 6 p. m.-	Aug. 4, 9 a. m. Emerging	27½	9½	Female
44	June 28, 11-12 a. m.	July 3-4	July 11-12	July 16-17	July 25-26	July 26, 9 a. m. Aug. 10, 12 m.	Aug. 18, 9 a. m.	42	?	Female
45	June 28, 1-4 p. m.	?	?	?	?	Beetle 1 day old July 24	Aug. 3, 9 a. m. Quite recent	26	9½	Male
46	June 28, 11-12 a. m.	?	?	?	?	11 a. m.-1 p. m. July 25, 6 p. m.-	Aug. 4, 10 a. m.	27½	9½	Male
47	June 28, 1-4 p. m.	?	?	?	?	July 26, 10 a. m. Aug. 1, 6 p. m.-	Emerging Aug. 10, 11 a. m.	34½	8½	Female
48	June 28, 11-12 a. m.	July 3-4	?	?	?	Aug. 2, 10 a. m. July 27	Just adult Aug. 6, 11 a. m.	29	9½	Female
49	June 29, 2:30 p. m.	?	?	?	?	3 p. m.-5:30 p. m. Aug. 5	Just emerging Aug. 15, 10 a. m.	37	?	?
50	June 29, 10-12 a. m.	July 3-4	?	?	?	10 a. m.-2 p. m. July 29	Beetle 24 hrs. old Aug. 7, 9 a. m.	30	9	Female
					?	10 a. m.-12 m.	Emerging			

*A 5th molt was found on Aug. 14th, but may have been shed two or three days earlier. Result of poor food.

RECORD OF DURATION OF LARVAL AND PUPAL STAGES—Continued.

Record	Date of Hatching.	Date of Shedding 1st Molt.	Date of Shedding 2d Molt.	Date of Shedding 3d Molt.	Date of Shedding 4th Molt.	Date of Pupating.	Date Adult Emerg.	No. of Days Larval Stage.	No. of Days Pupal Stage.	Sex of Beetle.
51	July 2 9 a. m.-1 p. m.	?	July 12	?		July 30, 6 p. m.- July 31, 9 a. m.	Aug. 10 Over 24 hrs. old	28½	?	Female
52	July 1-2	?	July 12	July 17	July 20	Aug. 4, 7 p. m.- Aug. 5, 9 a. m.	Aug. 13, 5 p. m. Aug. 14, 9 a. m.	34	9	Female
53	July 4-5	?	July 16-17	July 21-22	July 25-26	Aug. 8-10	August 16-17	35	?	Female
54	July 4, 7 p. m.- July 5, 9 a. m.	?	?	?	July 26, 12 m.	Aug. 5, 5 p. m.- Aug. 6, 9 a. m.	Aug. 14, 5 p. m.- Aug. 15, 9 a. m.	32	9	Female
55	July 7, 10-12 a. m.	July 12-13	July 16-17	July 20	?	Aug. 2 11 a. m. 2 p. m.	Aug. 11, 11 a. m. Just emerging	26	9	Female
56	July 8 11 a. m.-3 p. m.	?	July 17, 2 p. m. Just molted	July 22-23	July 29	Aug. 10, 2 p. m. Over 24 hours	Aug. 17, 2 p. m. Quite recent	31	?	Female
57	July 8 11 a. m.-5 p. m.	?	July 18-19	July 22-23	July 28-29	Aug. 8-10	Aug. 16, 11 a. m. Just emerging	31	?	Female
58	July 8, 9 a. m.	?	?	?	?	Aug. 6, 10 a. m.- Aug. 7, 11 a. m.	Aug. 15, 10 a. m. Quite recent	30	8½	Female
59	July 8 11 a. m.-5 p. m.	?	July 18-19	July 22, 12 m. Just molted	July 26-27	Aug. 4, 7 p. m.- Aug. 5, 9 a. m.	Aug. 14-15	28	?	Female
60	July 8 11 a. m.-5 p. m.	?	July 16-17	July 21, 5 p. m. Just molted	July 28-29	Aug. 8 10	Aug. 16, 9 a. m. Emerging	31	?	Male
61	July 12, 9-10 a. m.	?	?	Aug. 1, 10 a. m. Recent	Aug. 10, 3 p. m. Recent	Aug. 17, 2 p. m.- Aug. 18, 9 a. m.	Aug. 27, 11 a. m. Recent	36½	9½	Male
62	Aug. 3, 9 a. m.-12 m.	?	?	Aug. 27-28	Sept. 4-5	Sept. 16-18	Sept. 27, 3 p. m. Quite recent	44	?	Female
63	Aug. 7, 2-4 p. m.	?	Aug. 18-19	Aug. 24, 10 a. m. Very recent	Sept. 4, 11 a. m. Recent	Sept. 11, 3 p. m.- Sept. 12, 12 m.	Sept. 23, 11 a. m. Just adult	36	11½	Female
Approximate Average No. Days for Larval Stage for 63 Larvæ								33½	9½	
Approximate Average No. for Pupal Stage for 53 Pupæ								33½	9½	

(A question mark (?) indicates that a close record was not secured.)

(A double date indicates that molt occurred between the hours indicated or at night when no hours are given.)

LARVAL DEVELOPMENT FROM HATCHING TO PUPATION.

(These specimens were not often disturbed to secure exact date of molts.)

Rec. No.	Date of Hatching.	Date of 1st Molt.	Date of 2d Molt.	Date of 3d Molt.	Date of 4th Molt.	Date of Pupation.	No. Days Larval Stage.
64	June 2, 6 p. m. to June 3, 9 a. m.	?	?	?	?	July 14, 5 p. m. Just pup'd.	32
65	July 8, 11 a. m. to 3 p. m.	?	July 17-18	July 24, 1 p. m. Recent	July 31, 2 p. m. Recent	Aug. 16, 1 p. m. to 3 p. m.	39
66	July 8, 3 p. m. to 6 p. m.	?	?	?	?	Aug. 10, 7 p. m. to Aug. 11, 9 a. m.	33
67	June 10, 9 a. m. to 5 p. m.	June 15-16	June 19-20	June 30, 4 p. m. to July 1, 10 a. m.	July 4-5	July 12, 10 a. m. to July 13, 10 a. m.	32
68	June 9, 12 m. to 6 p. m.	?	?	July 7-8	July 10-11	July 19, 2 p. m. to 5:30 p. m.	30
69	June 22, 12 m. to 6 p. m.	?	July 5, 11 a. m. Just molted	July 10-16	July 17-18	Aug. 2, 10 a. m. to Aug. 3, 9 a. m.	41
70	June 22, 8 a. m. to 9 a. m.	June 26, 11 a. m. Recent	June 30, 10 a. m. to 4 p. m.	?	?	July 26, 12 m. to July 27, 10 a. m.	35½
71	June 22, 6 p. m. to June 23, 9 a. m.	?	?	?	?	Aug. 12-14	About 52
72	June 23, 11 a. m. to 4 p. m.	?	?	?	?	July 20, 10 a. m. to July 21, 9 a. m.	27½
73	June 26, 12 m. to 3 p. m.	July 1, 1 p. m. Just molted	?	?	?	July 31, 4 p. m. Just pupated	35
74	July 24, 9 to 10 a. m.	?	?	?	?	Aug. 22-23	About 30
75	July 24, 9 to 10 a. m.	?	?	?	?	Aug. 24-26	About 32
76	Aug. 3, 11 a. m. to 12 m.	?	?	?	?	Sept. 9-11	About 37
77	Aug. 3, 9 a. m. to 12 m.	?	?	?	?	Aug. 25-26	About 22
78	Aug. 3, 9 a. m. to 12 m.	?	?	?	?	Aug. 24-26	22
79	Aug. 11, 1 p. m. to 6 p. m.	?	?	?	?	Sept. 5, 4 p. m. to Sept. 6, 10 a. m.	25
80	Aug. 10, 5 p. m. to Aug. 11, 10 a. m.	?	?	Aug. 24, 11 a. m. Just molted	?	Sept. 3, 9 a. m. to Sept. 4, 10 a. m.	24
81	Aug. 28, 5 p. m. to Aug. 29, 9 a. m.	?	?	?	?	Sept. 27, 11 a. m. to 3 p. m.	29½

Approximate Average No. Days for 18 Larvæ.

A discussion of the larval development recorded in the above table will be found in connection with additional records of larval development in the following table. These latter specimens were not reared to the beetle stage because of the pupæ dying from one cause or another, or being used for other purposes. Some of the pupæ were preserved for future study of the pupal stage.

Approximate Duration of Larval Stage of 81 Specimens.

From the above tables it is learned that the larvæ numbered from 1 to 63 took an average period of 33 2-3 days from hatching to pupation.

Larvæ Nos. 64 to 81 took an average of 32 1-9 days, which is only a little less than the first sixty-three.

The last eighteen were not often disturbed for the purpose of obtaining the exact date of molting, hence they may be considered as developing practically without interference. This would seem to prove that the larvæ numbered 1 to 63, were not materially retarded by being so frequently disturbed. Thirty-three days or slightly less, may therefore be considered as a correct average for larval development.

Partial Records of Larval Development.

As already stated, in addition to the larvæ numbered 1 to 81, which were in all instances reared to maturity and the date of pupation recorded, 208 other larvæ were kept until after one or more molts had been secured. These records, a portion of which are shown in the following table, serve to furnish additional information on which the average age of the larvæ at the time of molting may be determined.

In the following table only the closest records obtained are recorded. While the table indicates a wide variation for the age of larvæ at the time of molting, the writer believes that it represents what actually occurs in the field under normal conditions.

The larvæ were reared in short sections of corn stalks and always kept in an outdoor wire-screened cage where the temperature conditions were nearly normal.

PARTIAL RECORD OF LARVAL DEVELOPMENT.

(All of these larvæ were either killed, died or formed imperfect pupæ.)

Record No.	Date of Hatching	Approximate Date of 1st Molt.	Approximate Date of 2d Molt.	Approximate Date of 3d Molt.	Approximate Date of 4th Molt.
83	June 2, 4:30 p.m.	June 6, 4 p. m. Just molted	(Killed June 16 Poor food.)		
86	June 6, 11 a. m.- 12 m.	June 10-12. Not close	June 16, 12 m.- June 17, 9 a. m.	(Not kept after 17th.)	
89	June 10, 12 m.- 6 p. m.	June 15, 5:40 p. m. Just molt- ing	(Died on June 22- 23.)		
92	June 13, 4 p. m.- 6 p. m.	June 20, 9 a. m. Within few hrs.	July 1 (?)	July 7-8	July 12, 6. p. m.- July 13, 9 a. m.
114	June 22, 11 a.m.- 3 p. m.	June 26-28	June 29-30	July 5, 11 a. m. Just molted	

PARTIAL RECORD OF LARVAL DEVELOPMENT—Continued.

Record No.	Date of Hatching	Approximate Date of 1st Molt.	Approximate Date of 2d Molt.	Approximate Date of 3d Molt.	Approximate Date of 4th Molt.
115-124	June 22, 11 a. m.-3 p. m.	June 26, 1 p. m. One just mlt'd.	N. B.—(Only one of these ten larvæ had molted 1st time June 26, 1 p. m.	Not observed later.)	
125-126	June 22, 8-9 a. m.	June 26, 12 m. Recently mlt'd.	?		
130-136	June 22, 11 a. m.-3 p. m.	?	June 30, 5 p. m. One, recently mlt'd.		
	N. B.—(Only one of these seven larvæ had molted the second time, June 30, 5 p. m. Not observed later.)				
144-145	June 22, 8-9 a. m.	?	June 30, 10 a. m.-4 p. m.		
147-148	June 22, 11 a. m.-3 p. m.	June 26, 1 p. m.-June 27, 10 a. m.	July 3, 11 a. m. Recently molted		
149	June 22, 11 a. m.-3 p. m.	?	July 1, 12 m. Just molted		
170-180	June 23, 12 m.-4 p. m.	June 27, 10 a. m. Two, recent	N. B.—(Only two of these eleven larvæ had molted 1st time, June 27, 10 a. m. Not observed later.)		
187	June 24, 10 a. m.	June 28, 6 p. m.-June 29, 2 p. m.	July 3, 3 p. m. Just molted	July 6, 4 p. m.-July 7, 11 a. m.	July 15, 12 m.-July 17, 2 p. m.
188-189	June 24, 10 a. m.	June 28, 10 a. m. Very recent	N. B.—(1st molt in less than 4 days.)		
193	June 26, 2-3 p. m.	June 30, 6 p. m.-July 1, 1 p. m.	July 5, 10 a. m. Just molted	July 11, 12 m. Just molted	July 18, 12 m.-July 19, 12 m.
194	June 26, 3-4 p. m.	July 3, 11 a. m. Very recent	July 6, 4:30 p. m. Just molted	July 11, 12 m. Just molted	July 17, 3 p. m.-July 18, 11 a. m.
195	June 26, 2-3 p. m.	June 30, 12 m.-5 p. m.	July 5, 11 a. m. Just molted		
203-205	June 27, 8-9 a. m.	July 1, 11 a. m. One, recent	N. B.—(Only one of these three larvæ had molted 1st time July 1, 11 a. m. Not observed later)		
206-214	June 27, 9 a. m.-1 p. m.	?	July 7, 10 a. m. Seven, molted		
	N. B.—(On July 7, 10 a. m., find that seven of these nine larvæ are past 2d molt. Other two molted only once.)				
215	June 27, 9 a. m.	July 1, 11 a. m. Very recent	July 5, 11 a. m. Just molted		
235-239	June 28, 12 m.-4 p. m.	?		July 17, 10 a. m. All quite recent	
241-242	June 29, 2:30 p. m.	July 4, 11 a. m. Both recent	N. B.—(Another larva hatched at same time had not molted July 4, 11 a. m.)		
244	July 8, 11 a. m.-5 p. m.	?	July 18, 11 a. m.-July 19, 10 a. m.		
245	July 8, 11 a. m.-5 p. m.	?	July 16, 12 m.-July 17, 9 a. m.		
246	July 8, 9 a. m.	July 17, 2 p. m. Recent	N. B.—(This larva was vigorous and growing. It was killed accidentally on July 20th, and had not shed 2d molt at that date.)		
247	July 8, 9-10 a. m.	July 17, 2 p. m. Just molted	N. B.—(This larva was small, and growing slowly although in good food.)		
260	July 8, 11 a. m.-5 p. m.	?	July 18, 11 a. m. Just molted	July 22, 11 a. m. Quite recent	July 29, 11 a. m.-July 30, 10 a. m.
263	July 12, 8-10 a. m.	?	?	July 28, 10 a. m. Recently molted	
264-271	July 12, 8-11 a. m.	?	July 21, 3 p. m. Two, recent		
	N. B.—(Only two of these eight larvæ were past 2d molt July 21, 3 p. m. Not observed later.)				
281	Aug. 3, 8-12 a. m.	?	?	?	Aug. 26, 10 a. m.-Aug. 28, 10 a. m.

PARTIAL RECORD OF LARVAL DEVELOPMENT—*Continued.*

Record No.	Date of Hatching	Approximate Date of 1st Molt.	Approximate Date of 2d Molt.	Approximate Date of 3d Molt.	Approximate Date of 4th Molt.
282	Aug. 3, 8-12 a. m.	?	?	?	Aug. 28, 10 a. m.— Aug. 29, 10 a. m.
283	Aug. 7, 2-4 p. m.	?	Aug. 31, 12 m.— Sept. 1, 10 a. m.	Sept. 8, 10 a. m.— Sept. 9, 10 a. m.	
285	Aug. 11, 6 p. m.— Aug. 12, 8 a. m.	?	?	Aug. 26, 11 a. m. Just molted	
286	Aug. 12, 8-12 a. m.	?	?	Aug. 27, 6 p. m.— Aug. 28, 9 a. m.	

NOTE: In the above table as in the previous table of larval development, many of the records for molts were made at about 24 hour intervals, as indicated by the double dates. The words "quite recent" or "very recent" indicate that the larvæ had molted within a few hours of the time when molt was found.

Age of Larvæ at Time of Molting.

The development of the larvae whose rate of growth is recorded under individual record numbers from 1 to 286, allows an opportunity of securing the average number of days between each molt even though complete records are available for only a few.

In the following table the number of days from hatching to shedding of first, second, third or fourth molt, is compiled from the foregoing records of larval development, but only the close records are included in this compilation.

The record numbers in the following table correspond to those in the previous table of larval development.

Larval Development by Molts.

Where a close record of hatching was secured and the molt is recorded as occurring at night, the latter time is figured as midnight for the purposes of this table. In the same manner when the egg hatched at night the time is counted as midnight if a close record of molt was recorded.

Table Showing Number of Days from Hatching to Each Molt.

(A fifth molt, sometimes occurring, is not taken into consideration.)

Record No.	No. of Days from Date of Hatching to:							
	1st Molt.		2d Molt.		3d Molt.		4th Molt.	
	Days.	Hours.	Days.	Hours.	Days.	Hours.	Days.	Hours.
1			21	6			39	20
2							27	
4	4	18	17	18	27	18	33	6
5							25	
6	4	6	11	6			22	16
8	6	11					21	20

LARVAL DEVELOPMENT BY MOLTS—*Continued.*

Record No.	No. of Days from Date of Hatching to:							
	1st Molt.		2d Molt.		3d Molt.		4th Molt.	
	Days.	Hours.	Days.	Hours.	Days.	Hours.	Days.	Hours.
9	5	9	10	9	14	9	21	9
10	5				30	13	35	13
11	5	6			14	6	23	6
12	4	12	13	12	17	12	25	12
13	6		10				21	10
15			11	10	17		25	
16	6	12	14	12	19	12	27	12
18			10	6	15	6	24	6
19	4	6	10	8	17	6	20	6
20	6	14	10	14			20	14
23							27	9
24							19	12
25							34	10
27	6	11	10	11	19	11	27	11
28	4	3	7	16				
29	6	11	12	11	18	11	22	11
33	4	21	9	10	12	10	25	
35	4	11			17	11	23	11
36	4	14	9	6	12	14	20	14
37			8	21	14	10	18	10
38	4	20	9	8	15	4	20	8
39	5	10	8	10	13	10	20	10
40			8	10	13	10	19	10
41	6	4						
44	5	12	13	12	18	12	27	12
47							23	9
48	5	12						
49							24	0
50	4	12						
56			9		14	12	21	12
57			10	10	14	10	20	10
59			10	10	14		18	10
60			8	10	13		20	10
61					20		29	5
62					24	12	32	12
63			11	9	16	19	27	20
65			9	11	16		23	
67	5	11	9	11	20	11	24	11
69			12	20	18	9	25	9
70	4	2	8	4				
73	5							
80					23	12		
83	4							
86		10	12					
89	5	3						
92	6	12			24	6	29	6
115	4							
125	4	2						
130			8					
144			8	4				
147	4	11	10	20				
148	4	11	10	20				

LARVAL DEVELOPMENT BY MOLTS—*Continued.*

Record No.	No. of Days from Date of Hatching to:							
	1st Molt.		2d Molt.		3d Molt.		4th Molt.	
	Days.	Hours.	Days.	Hours.	Days.	Hours.	Days.	Hours.
149			9					
170	3	21						
171	3	21						
187	4	14	9	7	12	14		
188	4							
189	4							
193	4	9	8	20	14	22	22	9
194	6	20	10		14	20	21	9
195	4		8	20				
203	4	2						
206			10					
207			10					
208			10					
209			10					
215	4	2	8	2				
235					18	20		
236					18	20		
237					18	20		
241	4	20						
242	4	20						
244			10	10				
245			8	10				
247	9	4						
260			9	21	13	21	21	10
263					16			
264			9					
265			9					
282							25	14
285					14	12		
286					15	15		

Average records obtained from this table are explained below.

Average Age at Which Larvæ Pass Molts.

A close study of the above record of larval molts furnishes complete data of the average age of the larvæ at the time of casting the successive molts.

Briefly summarized the record is as follows:

- 1st molt, 46 records, average age 5 days and less than 1 hour.
- 2d molt, 50 records, average age 10 days and less than 9 hours.
- 3d molt, 41 records, average age 17 days and less than 6 hours.
- 4th molt, 46 records, average age 24 days and less than 15 hours.

Last molt,—change of pupa—average age (see page —) nearly 33 days.

The duration of each larval instar was therefore found to be as follows:

1st Instar (hatching to 1st molt), approximately.....	5 days.
2d Instar (1st molt to 2d molt), approximately.....	5½ days.
3d Instar (2d molt to 3d molt), approximately.....	7 days.
4th Instar (3d molt to 4th molt), approximately.....	7½ days.
5th Instar (4th molt to pupation), approximately.....	8½ days.
Total average larval stage.....	33 days.

Considering the large number of records on which the above figures are based, it appears that this may be taken as a fair average record of larval development. The writer firmly believes that the development in the field does not differ materially from the figures secured by this work.

Summary and Additional Notes on Larval Development.

The shortest recorded time for full larval growth was 22 days, for two larvæ hatched August 3.

The longest recorded time for full larval growth was 53 1-2 days, for a larva hatched June 24.

Slow growth is usually the result of poor food, rather than cool weather, at least from the early part of June to the early part of September.

Slow growth of larvæ is recorded under the discussion of "Partial Second Generation," (page 133) but it has no practical bearing on the life history of the first generation.

A great variation in the rapidity of larval development during different instars was often recorded. In some instances the larvæ grew slowly until after the third molt, and then grew rapidly until ready to pupate. With others the reverse was true. Some larvæ grew slowly after the second or third molt, but still matured normally.

The larvæ cease feeding from a period varying from two to five or more days before pupating. The larvæ that matured in the shortest periods recorded seemed to feed until the second day before pupating, while the slow maturing larvæ sometimes lay dormant, or only occasionally active for fully a week before pupating.

Pupa.

Larvæ under normal conditions always prepare a cell in which to pupate, either in their feeding channel, or in the earth just beneath.

The pupa, or resting stage, assumed by the larvæ at the average age of 33 days, requires practically nine days to mature and for the adult beetle to emerge therefrom. The figures to sustain this statement are found in the table entitled "Duration of Larval and Pupal Stages" on page —, and in the additional records given in the following table. These last records of the pupal stage were secured from pupae reared from larvæ collected from cyperus plants in the fields around West Raleigh.

Twenty-seven adults were reared in this manner, but the exact duration of the pupal stage of some was not secured. This accounts for record numbers omitted in the following table.

DURATION OF PUPAL STAGE.*

Record No.	Date of Collecting Larva from Field.	Date of Pupation	Date of Maturing to Beetle Stage.	Sex of Beetle.	No. Days in Pupal Stage.
2	June 30 (large larva)	July 7	July 16	Female	9
3	June 28 (large larva)	9:30 a. m.-11:30 a. m. July 5, 12 m.- July 6, 11 a. m.	8 a. m.-11 a. m. July 13, 10 a. m. Only few hrs. old	Male	8
4	June 30 (large larva)	July 5, 12 m.- July 6, 12 m.	July 14, p. m.- July 15, 10 a. m.-	Female	9
7	June 21 (medium larva)	July 10, 7 p. m.- July 11, 9 a. m.	July 20, 10 a. m. Just emerged	Male	9½
8	July 7 (large larva)	July 11, 5 p. m.- July 12, 9 a. m.	July 20, 10 a. m.- July 21, 10 a. m.	Male	9
9	June 15 (small larva)	July 13	July 22	Male	9
12	June 30 (medium larva)	12 m.-5 p. m. July 16, 11 a. m.- July 17, 11 a. m.	11 a. m.-4 p. m. July 25, 10 a. m.- July 26, 10 a. m.	Female	9
14	July 15 (full grown)	July 21, 10 a. m.- July 22, 10 a. m.	July 31, 5 p. m.- Aug. 1, 11 a. m.	Female	10
15	July 7 (large larva)	July 24, 10 a. m. Recently pupated	Aug. 3, 9 a. m. About 12 hrs. old	Male	9½
16	June 30 (large larva)	July 24, 2 p. m. Just pupated	Aug. 2, 6 p. m.- Aug. 3, 9 a. m.	Male	8½
18	July 7 (large larva)	July 19, 11 a. m.- July 20, 9 a. m.	July 29, 9 a. m. Just emerged	Female	8½
20	June 30 (small larva)	July 21, 6 p. m.- July 22, 9 a. m.	July 30, 10 a. m.- July 31 9 a. m.	Female	9
22	June 30 (small larva)	July 30 10 a. m.- July 31, 9 a. m.	Aug. 9, 10 a. m.- Aug. 10, 9 a. m.	Female	10
24	July 28 (full grown)	July 31, 5 p. m.- Aug. 1, 9 a. m.	Aug. 9, 10 a. m.- Aug. 10, 10 a. m.	Male	9
25	July 28 (large larva)	Aug. 6, 11 a. m.- Aug. 7, 11 a. m.	Aug. 14, 9 a. m.- Aug. 15, 9 a. m.	Female	8
27	June 20 (small larva)	Aug. 25-26	Sept. 3-4	Female	8
Average Duration of Pupal Stage approximately					9

NOTE: (A more extensive record of pupal stage is given in a previous table. Page —)

*These pupæ were reared from larvæ collected from cyperus plants in the field on the dates recorded.

Summary of All Records of Pupal Stage. With Additional Notes.

The last table gives the approximate pupal stage for 16 individual pupæ and the table on pages 117 to 120 gives a similar record for 53 individuals. The total average for both series, comprising 69 pupæ in all, is only a fraction above nine days.

Eight days approximately, is the shortest time in which the pupæ can mature, and ten days is the longest time.

The normal development of the pupa is not materially affected by heat or moisture conditions during the summer months. Many of those reared during the course of this work, were forced to pupate on dry soil, a procedure rendered necessary at times to avoid injury by mites.

Most of the pupæ transformed in a cell which was formed either in the corn stalk in which the larvæ matured or in the soil underneath their food.

The pupal stage is ordinarily assumed in a well formed cell, generally lined with the fiber of the plant in which the larva fed during its growth. In some instances the larva drags particles of fiber into the soil to line the cell for the pupa. In the field the pupa is frequently found in a compact earthen cell, not lined in any manner, except for having the inside smoothed and probably hardened with secretions by the full grown larva.

A pre-pupal stage is always noticeable. That is, the larva assumes an elongated, cylindrical form, while the body becomes somewhat stiff and rigid. This may be noticed for one or two days before the transformation to pupa takes place.

Life Cycle of Individuals From Egg to Adult.

The foregoing records of egg hatching, larval and pupal development and emergence of adult beetles may be summarized to show the average duration of the life cycle under normal summer weather conditions, as follows:

Average Duration of Life Cycle.

	<i>Average.</i>
Approximate average duration of egg stage.....	6 days.
Approximate average duration of first instar	5 days.
Approximate average duration of second instar	5½ days.
Approximate average duration of third instar	7 days.
Approximate average duration of fourth instar	7½ days.
Approximate average duration of fifth instar	8½ days.
Approximate average duration of pupal stage	9 days.
Total life cycle, egg to adult.....	48 days.

The above figures give the average life cycle secured from all the breeding records. It will be noted that the life cycle of 48 days is not based on the average between the extreme minimum and maximum records secured, but on an average of the total records. The average duration of the larval stage alone is 33 days, as already explained; if, however, we should take the average between the shortest larval duration of 22 days and the longest of 53 1-2 days, as given in a previous table, we would have 37 3-4 days for average larval development. This one illustration serves to prove that the average of the total figures secured from many records during the season, is what we need for a life history study of any insect.

The minimum life cycle, counting five days for the egg, twenty-two days for the larva, and eight days for the pupa, is only thirty-five days, which is certainly much below the average.

The maximum life cycle, allowing ten days for the egg, fifty-seven days for the larva and ten days for the pupa is seventy-seven days, or two and one-half months, a slow development that would perhaps never occur except with a few late individuals.

Enemies and Diseases of Larva and Pupa.

No internal parasites for either the larva or the pupa have been discovered. It is probable that none exist, except possibly in very exceptional cases.

Mites have proved to be a pest of both the larvæ and the pupæ in confinement, but field observations do not show that the same thing is true under perfectly normal conditions. During the breeding work, many larvæ are apparently killed, or worried so as to prevent regular growth, by a small mite identified by Mr. Banks as *Tyroglyphus americanus* Bks. These mites were often found on the bodies, or in their feeding channels, and usually such larvæ did not grow well. Very young larvæ were sometimes killed by the mites.

Both larvæ and pupæ were sometimes found with a portion of the body blackened, evidently by some fungus growth. However, no real evidence was secured to prove that the larvæ or pupæ were ever killed by fungus or bacterial disease.

Adult.

The adult beetle stage has been observed both in the field and in confinement. The first beetles collected during the latter part of June, 1910, were kept alive, as already stated, until March 1, 1911. At the present date, December, 1911, in the breeding cage where the life history work was conducted, there are now a number of beetles alive, which were collected May 26, 1911, and some of them are the ones whose egg-laying record has been recorded. There are also about fifty beetles which were reared from eggs during July, August, and September. Of the total number reared in confinement, that is, sixty-three, as shown in the rearing records, only one commenced to lay eggs for a second generation. The record of this one female is given in the latter part of this report under a discussion of "Partial Second Generation." The possibility of an extensive second generation is very remote, and we may, therefore, consider one generation each year as the normal condition.

Feeding Habit of Adult Bill-Bugs.

The beetles reared last summer during the breeding experiments commenced to feed about the fifth day after emergence. These beetles were usually in cells in which they could readily escape. A few matured in cells in the soil and did not emerge for about two weeks, but in such cases they commenced to feed the first day after appearing above ground. The beetles that mature in the field undoubtedly feed after emergence until cold weather drives them into hibernation. In the breeding cage the reared beetles fed on corn stalks supplied as food, until after the middle of October. Most of the beetles fed every day until that time.

Damage to young corn plants is caused by the beetles eating into the stalk at or below the surface of the ground, often making slits a half inch or more in length with their thin chisel-like beak, on the end of which the true biting jaws are located. Small plants are killed outright. Corn plants that have attained a height of eight or ten inches before being attacked are not usually killed, but grow crooked and dwarfed and never make a normal growth. The larger plants are also stunted by the larvæ feeding in the root, or in the stalk just above the root.

The writer has never discovered that the bill-bugs feed on any plants except corn, and species of *Cyperus*. Other writers state that bill-bugs

feed on many sedges, which may be true, but such statements may have been based on the feeding of other species than *Sphenophorus callosus*.

The most natural position for the beetles when feeding is to stand head-downward, with the legs clasped around the food plant, and the beak buried more or less in the tissue of the plant. The powerful leg and foot hold is quite characteristic of these beetles. It requires a strong pull to remove beetles when they are settled for feeding.

Duration of Beetle Stage.

As has already been stated beetles collected on June 20, 1910, lived until March 1, 1911.

Those beetles represented the 1909 generation and must have matured during July, August or September of 1909. Considering that they matured on the first of September, 1909, and lived until March 1, 1911, their age was fully eighteen months at the time of their death. The writer believes that further experiments will prove that some beetles may live two years or more. The beetles that died on March 1, 1911, would no doubt have lived longer if they had not been disturbed to see how many were alive during the months of January and February, 1911.

At the present time, December 10, 1911, the writer has one beetle that matured between August 3 and 9, 1911, commenced to lay eggs August 26, 1911, laid twelve eggs before September 13, and is now alive, buried in earth in a jelly glass. With this exception none of the reared beetles showed any signs of mating or egg laying. All evidence points to the fact that the beetles normally mature and feed during the fall months, hibernate in the soil or in corn stalks (see discussion of hibernation), emerge in spring during March or April, commence egg laying about May 25, continue egg-laying for from two or four months, and finally die off during the late fall months or else hibernate and live at least a portion of the second winter. It is yet to be proved that any of the beetles live to emerge the second spring, but we have no evidence to prove that this does not sometimes occur.

Food Plants.

The larvæ of *Sphenophorus callosus* have been found in the following plants:

Corn, in all localities where bill-bugs have been observed.

Rice, in all localities where rice is grown in bill-bug sections which have been visited.

Cyperus flavicomus, at Raleigh, in large numbers.

Cyperus cylindricus, at Proctorville and Braswell. (Only few.)

Cyperus strigosus, at Lumberton and Chadbourn.

Cyperus overlaris, at Pembroke. (Many plants infested.)

Cyperus esculentus (common chufa), around West Raleigh. Very common in this locality, where the plants are known as nutgrass.

Corn, rice and the larger species of *Cyperus* are undoubtedly the main food-plants in North Carolina.

I have collected as many as ten adult beetles from beneath a single large plant of *Cyperus flavicomus* which in this section sometimes grows in clumps of ten or more plants. The field of *Cyperus esculentus* at

West Raleigh, where *Sphenophorus callosus* bred freely this past summer, consisted of plants that seldom grew large enough to support more than one larva. During the months of July and August larvæ of all sizes, and frequently pupæ, were found readily at the base of these plants.

Hibernation.

The bill-bugs hibernate ordinarily in the beetle stage. This statement is made without reservation and is based on many field observations during the winter of 1909-1910, when careful search on several occasions failed to reveal any eggs, larvæ or pupæ, in the field where bill-bugs were known to have bred during the previous falls. It has proved to be extremely difficult to find any bill-bugs in their winter quarters, but the total absence of larvæ and pupæ in the breeding places proves that the winter is not passed in either of those stages.

Only one record has been secured of actually finding the beetles in a place where they presumably pass the winter. On November 4 and 5, 1911, in company with Mr. J. A. Hyslop, of the National Bureau of Entomology, adult bill-bugs were found in corn stubble in a field on Harvey's Neck in Perquimans County. The trip to this field was made for the express purpose of trying to find the beetles, for it was assumed if any were found on that date that they would be in hibernation for the winter. After considerable search we located a dead beetle in a corn stalk. This beetle was at a point in the stalk about even with the surface of the ground. Soon afterward we found another dead beetle in a similar location. On the second day three live beetles were found in corn stalks in a field where serious bill-bug damage had occurred during the summer. Apparently these beetles had matured late and had not attempted to escape. We consider this to be proof of the hibernation actually occurring in the corn stalks. The beetles were in the stalk near the roots, where the larva had fed and transformed.

During these two days when beetles were found in corn stalks, we also searched for the beetles, and the immature stages, in *Cyperus* plants, but without success. In fact, there were only a few *Cyperus* plants found in which *Sphenophorus* larvæ had lived. The writer believes, however, that the bill-bugs had bred in *Cyperus* in these fields in plants that had died down and become invisible.

Hibernation must also occur in the soil, or under the protection of some material in the fields, as well as in corn stalks. The breeding of beetles during the past summer, when every reared specimen emerged and fed nearly every day thereafter until the middle of November, shows that it is the natural thing for the beetles to come out and feed after maturity. If this is true the majority of the bill-bugs are not hibernating in corn stalks unless they crawl into the stalk when cold weather commences. That this actually occurs is extremely doubtful. The beetles found in the corn stalks had certainly never emerged and no beetles were found under conditions to indicate that they had crawled into the stalk.

On November 5, 1911, Mr. Hyslop found one healthy live pupa in a corn stalk. This indicates a possibility of the pupæ living in that situ-

ation all winter. The rearing records, however, do not indicate that pupæ are liable to live all winter. This point needs further investigation, but in view of present knowledge we may consider that only the mature beetles normally live during the winter.

The writer has searched for the beetles in winter quarters in fields at Lumberton, Chadbourn, Braswell, Pembroke, and other places, including the fields around West Raleigh, where many bill-bugs bred during the last two seasons. Without recording details of the work it may be stated that the beetles have never been discovered during the winter months, that is, December to March inclusive, except in one instance at Chadbourn, when a single specimen was taken in the edge of a rice field on March 29, 1911. On that date one beetle was found in a clump of grass, where it was moving about, hence it was not exactly in hibernation. Sticks, stones, logs, dead grass and weeds, brush, and, in fact, every movable thing in the field, have been overturned in the search for beetles in hibernating quarters other than corn stalks.

Summary of Seasonal Life History.

Without considering a partial second generation, which is only of minor importance, the seasonal life history of the corn bill-bugs may be stated as follows:

Eggs are first laid about May 20, in corn plants or the larger species of *Cyperus* and possibly in other sedges. The eggs require an average of six days for hatching. Egg laying continues until the latter part of September.

The larvæ feed in the stalk or root of the plants and become full grown in an average period of about thirty-three days.

Larvæ of all ages occur from June to after November 30, but the majority are full grown before November 1.

The pupæ occur in cells in the stalk of the food plant or in the soil underneath the roots. Nine days is the average duration of the pupal stage.

The beetles mature and usually emerge and feed during the months from July 1 to November 1 or later. These beetles do not often mate and lay eggs until the following spring, after emerging from hibernation in which they pass the winter.

*Partial Second Generation of *Sphenophorus callosus*.*

In the preceeding report, covering the breeding experiments with this species, mention is made of a partial second generation, based on the record of one reared female that laid fertile eggs, the larvæ from which were reared to different ages. No pupæ were secured from these larvæ, but the writer believes this to be due to improper food and handling, rather than to the inability of the larvæ to attain full growth and pupate. As no beetles of the second generation were actually reared this can not really be considered as a true second generation. The reader will understand, however, that the larvæ under suitable conditions would have matured and pupated, and adults might then have been secured. The writer believes that a partial second generation does occur occasionally.

During the past season, as the records show, 56 female bill-bugs were reared from eggs or from larvæ collected from *Cyperus* plants. Only one of these 56 females commenced to lay eggs. This one female was secured between August 3 and 9—the exact date, unfortunately, not recorded—and after feeding on corn plants for about two weeks she commenced to lay eggs between August 26 and September 1. On the latter date, when the eggs were found, this beetle was confined with two other females and two males. These three females were at once separated and watched carefully for several weeks to prove that only one continued to lay. Previous to September 1, and for several weeks afterward, all the reared beetles were furnished fresh food every two or three days, and this food carefully examined when removed. In this way it was ascertained that no other female except the one mentioned, ever laid eggs, and, in fact, no sign of mating was ever observed.

Record of One Female Which Laid a Few Eggs For Second Generation in 1911.

Five eggs were first found on September 1, when the female was about three or four weeks old. Her egg-laying record was as follows:

Between August 21 and September 1, laid.....	5 eggs.
September 2, laid.....	1 egg.
September 3, laid.....	0
September 4, laid.....	2 eggs.
September 5 and 6, laid.....	0
September 7, laid.....	1 egg.
September 8, laid.....	0
September 9, laid.....	2 eggs.
September 10 and 12, laid.....	0
September 13, laid.....	1 egg.
From September 13 to October 27.....	0
Total.....	12 eggs.

This female was kept under observation until October 27, but laid no eggs after September 13. On October 27 she was alive and active, and on November 20 when last seen, she was still alive, but buried in soil preparatory to hibernating there during the winter.

The eggs secured were hatched in about six or seven days. No accurate record was kept, but all the eggs hatched as quickly as did eggs of the first generation, which were still being secured during the same period.

Partial Larval Development of Second Generation.

Nine larvæ were reared to partial development, but on account of improper food none of them matured. The individual records of some of these larvæ are given below:

LARVA No. 1.—Hatched September 2-4; placed in corn stalk September 4, 9 a. m. Not seen until September 15, when it was found dead after growing only a little and evidently past first molt. Death evidently due to hard, dry food.

LARVA No. 2.—Hatched September 4-5; placed in corn stalk September 5. Not seen again until October 10, when it had attained about two-thirds usual

size of mature larva; next seen on November 14, when it was still alive but not feeding, and had not grown much since October 10; found dead November 20. Death probably due to improper food.

LARVA No. 4.—Hatched September 26; placed in food about 1 p. m. September 16, seems to be feeding and growing naturally. September 27, found dead; cause unknown; larva does not look discolored; had passed second molt.

LARVA No. 7.—Hatched September 19-20; placed in food September 20. September 29, feeding and growing. October 2, larva killed accidentally.

The writer wishes it understood that the larvæ of the second generation were fed in sections of large corn stalks which evidently did not furnish good food. As this work was not anticipated no young corn plants had been provided for and it was found difficult to secure suitable food for rearing the larvæ. In the field the beetles may lay eggs in large *Cyperus* plants in which the larva could get the proper food. If that occurs there is every reason to suppose that adults of the second generation may occasionally mature. The fact that larvæ were reared to practically full growth in poor food shows that they might readily mature if good food were obtainable.

There is only a slight probability, however, that any extensive second generation usually occurs. The notes recorded above, if considered in connection with all the rearing records, indicate clearly that it is not usual for the females to lay eggs for a second generation.

BIOLOGICAL RECORD OF LITTLE GRASS BILL-BUG.

Sphenophorus Parvulus.

BY

R. I. SMITH.

The study of the life history of *S. parvulus* conducted during the season of 1911 was originally commenced as a minor part of the Adams Fund Project entitled "Biological Investigation of *Sphenophorus callosus* and Other Injurious Species of This Genus Occurring in North Carolina," upon which the writer worked almost exclusively from April to November, 1911. The biological records with *S. callosus* have been recorded in a separate article.

The little grass bill-bug is not known to be a serious pest in North Carolina, although it may do more damage than we are aware of. The present report covers only a life history study of this species. The writer has no data concerning the damage caused by this insect. The North Carolina Station collection of insects did not, before this year, contain any specimens of this insect, although it was known to occur in the State.

The notes and records which follow are submitted as a scientific report of the egg-laying habits, egg-laying record, and larval and pupal development; also the number of generations occurring annually. The conditions under which this work happened to be undertaken, together with the records secured, serve to make this report of peculiar interest, as a biological problem.

On May 19, 1911, one small beetle of this species was collected from a low ground corn field on Rocky Creek, less than one-half a mile from the writer's office and laboratory. This specimen proved to be a fertile female which commenced to lay eggs on May 21 or 22. On the latter date three eggs were found in the corn stalk which had been furnished the beetle for food. At that time, and for the remainder of the season, this lone female was confined in a jelly glass and provided with sections of green corn stalk for food. Three other beetles of the same species were collected about the same time, but they all died within a few weeks; hence the season's work was based on the record of this lone female and her progeny.

Egg-laying Record of One Female, S. Parvulus.

As already stated, the female, collected May 19, commenced to lay eggs on May 21 or 22. After the latter date, when the first three eggs were found, this beetle was carefully fed and tended, in order to secure her full egg-laying record. A daily record, with only a few exceptions, was secured, as shown in the table which follows. Green corn stalk was the food provided, in which all the eggs were placed.

During this egg-laying existence the beetle was kept in a jelly glass, in a wire screened room used for an outdoor laboratory. Her environment was somewhat artificial, but moisture and temperature conditions were about normal.

DAILY EGG-LAYING RECORD OF ONE FEMALE, COLLECTED MAY 19, FROM CORN FIELD.

Date in 1911.	Number of Eggs.	Date in 1911.	Number of Eggs.	Date in 1911.	Number of Eggs.
May 22	3	July 2-3	missed	August 11	2
May 23	1	July 4	1	August 12	3
May 24	1	July 5	1	August 13-15	1
May 26	1	July 6	1	August 16	1
May 27	1	July 7	5	August 17	5
May 28	2	July 8	4	August 18	4
May 30	1	July 10	3	August 19	4
May 31	2	July 11	4	August 20	1
June 1	1	July 12	3	August 21-23	2
June 2	1	July 13	4	August 24	4
June 4	1	July 14	1	August 25-26	1
June 5	1	July 15	1	August 27	5
June 7	1	July 16	.	August 28	3
June 8	3	July 17	1	August 29	4
June 9	1	July 18	4	August 30	4
June 11	3	July 19	3	August 31	2
June 12	3	July 20	2	September 1	1
June 13	1	July 21	4	September 2	2
June 14	1	July 22	1	September 4	3
June 15	2	July 23	7	September 5	1
June 16	2	July 24	4	September 6	2
June 17	1	July 25	3	September 7	1
June 18	3	July 26	4	September 8	2
June 19	2	July 27-28	5	Sept. 9-11	2
June 20	2	July 29	3	September 13	1
June 21	2	July 30	3	September 15	1
June 22	2	July 31	1	September 19	1
June 24	7	August 1	3	September 20	1
June 25	1	August 2	3	September 22	1
June 26	1	August 3	4	September 23	1
June 27	3	August 4	4	September 25	1
June 28	2	August 5	2		
June 29	1	August 6	4	September 29	2
June 30	3	August 7	3	October 7	1
July 1	4	August 8-9-10	17	October 8-27	0
				Total -----	255

Notes Concerning Egg-laying Record.

Two hundred and fifty-five eggs were laid between May 19 and October 7, a period of 142 days, or over four and one-half months. Seven eggs was the greatest number laid in any twenty-four hour period.

The female was alive and healthy on October 27, when daily observations were discontinued; and she was still alive but lying buried in the soil on November 20, when last seen.

In the above record where a daily date is omitted entirely it means that no eggs were laid, but when the egg record for two or three days is united it means that the eggs were not removed until the latter date.

Egg-hatching Record.

The eggs secured during the laying record recorded above proved to be fertile and many of them were hatched to secure larvæ for rearing. Only a very few close egg hatching records were recorded; from these the average incubation period proved to be about seven days during the early days of June, and about six days during July and August. During the last of September, when much cooler weather prevailed, some eggs took fully eleven days to hatch.

The average incubation period for warm summer weather is no doubt as low as six days, or about the same time required for eggs of *S. callosus* to hatch.

Rearing Records From Egg to Beetle.

The larvæ, immediately after hatching, or within less than twenty-four hours were placed carefully in a corn stalk for the purpose of determining the length of the larval stage and for rearing pupæ and adult beetles. All of the larvæ were reared in a section of corn root taken from the field. The plant was usually cut off three or four inches above the root. In this short section a hole was cut into one side, the newly hatched larvæ carefully introduced, after which the opening was closed by replacing the surface of the piece removed; this was then secured by a rubber band. These sections of corn plants were usually kept on moist earth. Frequent observations were made to determine the location and development of the larvæ. It was found difficult to get the young larvæ established, but out of a considerable number handled in this manner I succeeded in rearing four beetles, which matured in a healthy condition and commenced to feed within a few days after emergence. Three pupæ were also reared, but died before transforming to the beetle stage. Over twenty additional larval records were secured, representing specimens that lived for a short time only, or became apparently full grown, but failed to pupate from one cause or another.

These statements refer to larvæ of the first generation only, the progeny of the female whose egg-laying record has been recorded. A partial second generation was reared, as recorded farther on.

The larvæ of this species are small and delicate, when first hatched, rendering it difficult to watch their growth in corn stalks without injuring some specimens, and doubtless causing a slow growth of some that mature in spite of being frequently disturbed. For this reason it is possible that the records of larval development in the following tables may show a slower growth than really occurs in the field.

Rearing Records.

(For first generation in 1911, including all notes of importance made concerning each specimen.)

Nos. 1 to 4, inclusive, reared from egg to beetle stage.

Nos. 5 to 7, inclusive, reared only to pupa stage.

Nos. 8 to 21, inclusive, are records of partial larval development.

RECORD No. 1.—Egg laid June 11 after 6 p. m.; hatched June 19 after 6 p. m.; pupated July 29-30; adult found August 10.

RECORD No. 2.—Egg laid June 29-30; hatched July 6, before 10 a. m.; pupated August 15; adult August 24, 9 a. m.

RECORD No. 3.—Hatched July 4-5; pupated August 12, 9 a. m.; adult just emerged August 20, 10 a. m.

RECORD No. 4.—Hatched July 26 to 28; pupated September 25; adult October 4.

RECORD No. 5.—Egg laid August 3-4; hatched August 10-11; pupated September 10-11.

RECORD No. 6.—Egg August 3-4; hatched August 10-11; pupated September 17-18.

RECORD No. 7.—Egg August 28-29; hatched September 4-5; pupated about October 20.

RECORD No. 8.—Hatched July 18-19; full grown about August 16; died August 30.

RECORD No. 9.—Hatched August 20-21; about full grown August 17; dead August 24.

RECORD No. 10.—Hatched July 29-30; full grown September 4; died September 11.

RECORD No. 11.—Hatched July 29-30; nearly full grown September 29; dead October 10.

RECORD No. 12.—Hatched August 3-4; nearly grown August 26; dead August 29.

RECORD No. 13.—Hatched September 8, 10 a. m.; about full grown October 14; dead November 6.

RECORDS Nos. 14 to 21, INCLUSIVE.—The larvæ numbered from 14 to 21 were hatched on dates ranging from June 8 to September 30, but none of them thrived in their artificial environment. Their records are not sufficiently complete to be recorded in detail.

SUMMARY OF LIFE CYCLE AS SHOWN BY RECORDS.

The record numbers correspond to those in preceding records.

The record by days is approximate, not exact.

Record Numbers.....	1	1	3	4	5	6	7
Number of Days for Egg Hatching.....	6	6½	?	?	7	7	7
Number of Days for Larval Growth.....	40	41	33	60	34	38	46
Number of Days for Pupal Stage.....	9	9	8	9½	?	?	?

This table shows that the larval stage for the seven specimens recorded varied from 31 to 60 days, a condition which the writer believes to be comparable with normal field conditions.

The pupal stage undoubtedly covers about nine days, dependent somewhat on heat and moisture conditions. Moisture, however, does not seem to be as necessary as warmth, for some of the pupa developed normally in a very dry cell.

Partial Second Generation.

During the season of 1911 four beetles of this species were reared from eggs, as recorded in the first portion of the report on this insect. Of these four beetles one commenced to lay eggs for a second generation. The eggs secured were hatched and an attempt was made to rear the larvæ to maturity. This attempt, however, was unsuccessful on account of not being able to furnish the larvæ with proper feed. Over fifteen larvæ were reared to partial maturity; seven of them reached full growth but did not pupate; one larva attempted to pupate, but died in the attempt. The work, however, shows that a second generation may occur if the proper conditions prevail.

Record of One Female Which Was Reared and Laid Eggs for a Second Generation.

This female matured about August 20, commenced to feed August 26, and had laid four eggs on September 6. Including the eggs found on that date her record was as follows:

September 6, found.....	4 eggs.	September 18, found.....	3 eggs.
September 7, found.....	1 egg.	September 21, found.....	1 egg.
September 9, found.....	6 eggs.	September 23, found.....	1 egg.
September 11, found.....	5 eggs.	September 25, found.....	2 eggs.
September 13, found.....	4 eggs.	September 27, found.....	0
September 16, found.....	0		
Total laid in 19 days..... 27 eggs.			

After September 27 the female was observed frequently until October 23, but she did not lay any more eggs. She was alive and active on November 14, but was found dead on December 8. Hence the opportunity is lost to determine if a female that lays eggs in this manner is capable of living through the winter and continuing to lay eggs again the following spring.

This female was reared in a short section of corn stalk, and, after maturity, was kept in a jelly glass, on rather dry earth. Her food was short sections of green corn stalk, replenished every two or three days. After the first of October it was difficult to get succulent corn stalks for food, but it seems probable that the beetle could not have found a much better food supply in the field.

Brief Notes on Rearing Larvæ of Second Generation.

Fifteen larvæ were reared to partial maturity. Of this number one attempted to pupate, but failed; it was found dead with larval skin partly shed. Six larvæ reached about full growth but died because of poor food evidently. The remainder never attained half size.

I. STUDIES IN COTTONSEED MEAL INTOXICATION.¹*As to Pyrophosphoric Acid.*

BY W. A. WITHERS AND B. J. RAY.

WITH THE COLLABORATION OF R. S. CURTIS AND G. A. ROBERTS.

The injurious effect from the continuous feeding of cottonseed meal to calves and swine has been known for years. The cause has been regarded by various investigators² as lint, oil, high protein content, a toxalbumen, cholin, betain, resin and decomposition products. Crawford³ in a preliminary paper published in March, 1910, states that "The chief poisonous principle in certain cottonseed meals is a salt of pyrophosphoric acid." Crawford's conclusion is based upon the study of an extract obtained by digesting the meal at body temperature one day with pepsin and one day with pancreatin. He fed with a catheter extracts of cottonseed meal, these extracts corresponding to amounts of meal very much in excess of those which would be fed ordinarily. He made no study of undissolved residues.

We began the study of the subject August 19, 1908, and since that time have used many solvents in our efforts to extract the toxic substance. The undissolved residue having proved toxic in every case we decided to investigate the residue undissolved by the pepsin pancreatin treatment. We also tried other feeds which bear upon the question.

The animals selected were rabbits. Our normal daily feed for each animal was 15 grams of cottonseed meal, or an amount of some fraction equivalent to 15 grams of meal. As the rabbits used averaged about 1.5 kilos the daily feed corresponds to 10 grams per kilogram of initial live weight. The feed refused was estimated and correction made. Each animal was allowed peavines, cabbage leaves or other green feed each morning. We mixed molasses with the cottonseed meal, and when some fraction of the meal was being fed the portion of meal removed was replaced by an equivalent weight of wheat bran. Six controls were run during the entire time of the experiment and all the control animals lived. The feeds, daily and total, are all calculated to the equivalent in grams of cottonseed meal per kilo of initial weight of animal.

Feed No. 67. Pepsin and Pancreatin Extract—Forced Feeding.
Started June 2, 1910.

Raw cottonseed meal was digested one day each with pepsin and pancreatin. The mass was filtered, and the filtrate concentrated to small volume. The solution was fed through a catheter in amounts corresponding to 200 grams of meal.

¹This paper was read before the Biological Section of the Am. Chem. Soc. at its Washington meeting, December 1911, (except the results of Feed No. 182). This paper appears in the Journal of Biological Chemistry, March, 1913.

²Journal of Pharmacology 1, (1910) 547.

³Experiment station record 22 (1910) 502.

Nine rabbits were taken, varying in weight from 1461 to 2240 grams, average 1752. All lost in weight an average of 123 grams. Two were made very sick, but survived; two showed no ill effect except loss in weight, and five died. The amount fed corresponded to ten times our normal feed of cottonseed meal. The P_2O_5 in the feed was 2.22 gms.

Feed No. 73. Sodium Pyrophosphate. Started May 16, 1911.

Sodium pyrophosphate was prepared in the laboratory by igniting disodium phosphate. The product responded to the tests for pyrophosphate and for freedom from orthophosphates. 4.157 grams corresponded to 2.22 grams P_2O_5 , the amount contained in the pepsin pancreatin extract of 200 grams of meal (Feed No. 67). The pyrophosphate for each animal was dissolved in 65 c.c. of water and fed through a catheter.

One rabbit weighing 2070 grams was fed on May 16, 1911, and died that night. Another rabbit weighing 1456 grams was fed on July 11, 1911, and died in 31 minutes.

The results with our feeds 67 and 73 indicate that the pepsin pancreatin extract of 200 grams of meal is generally toxic when given at one feeding and that the $Na_4P_2O_7$ corresponding to the amount of P_2O_5 in that amount of meal is toxic if administered at a single feeding.

Feed No. 120. Cottonseed Meal. Started April 23, 1911.

Twelve rabbits were taken whose initial weight ranged from 970 to 2560 grams, the average being 1559 grams. All the animals died within from eight to 21 days, average 13 days. The average loss in weight was 379 grams. The total amount of meal consumed by each animal ranged from 105 to 225 grams, average 157 grams. The total amount eaten was practically 100 grams per kilo of initial weight of the animal, making an average daily consumption of meal equivalent to 7.7 gms. per kilo of animal. These figures indicate the degree of toxicity of the meal towards the animals under the conditions of the experiment. There were 2.76 grams of P_2O_5 in the average feed or 0.21 grams in the daily feed.

Feed No. 124. Sodium Pyrophosphate Corresponding to Whole Meal. Started April 27, 1911.

Our cottonseed meal contained 1.76 per cent of P_2O_5 . If it were all in the form of pyrophosphate, 0.4157 grams of sodium pyrophosphate containing 0.222 grams of P_2O_5 would contain an amount equivalent to 12.5 grams of meal.

Four rabbits varying from 790 to 1550 grams, average 1117 grams, were fed daily 0.4157 grams $Na_4P_2O_7$. Each animal gained in weight, the average gain being 243 grams. At the end of 52 days the feed was discontinued, all the animals being in good condition. For each kilo of animal the equivalent of the feed in cottonseed meal was total 582 grams, daily 11.2 grams.

This feed furnished each animal daily with more pyrophosphoric acid than the amount received by each animal eating the raw meal, yet this

feed was non-toxic and the meal toxic. This indicates that pyrophosphoric acid is not the cause of toxicity in cottonseed meal.

Our next step was to ascertain which was the more toxic portion of the meal, the aqueous extract, the pepsin-pancreatin extract of the residue undissolved by water, or the residue undissolved after both of these treatments.

For the purpose we prepared feeds Nos. 170, 171, and 172.

*Feed No. 170. Aqueous Extract Cottonseed Meal. Started
October 23, 1911.*

1260 grams of cottonseed meal were stirred at room temperature with 1050 c.c. water and 10 c.c. chloroform for 24 hours. The solution was filtered, the liquid evaporated over a waterbath to a syrup, poured over 240 grams of bran, mixed thoroughly, dried, and fed to each animal in amounts corresponding to 30 grams of cottonseed meal daily—twice our normal feed. Six animals were taken. One animal died after 16 days, having lost 369 grams. The death being from causes other than the feed the observations are not included. The other five animals ranged in weight from 1137 to 1947 grams, average 1400. The feed was discontinued after 38 days, the animals having gained an average of 203 grams. There were 2.26 grams of P_2O_5 in the total average feed, or 0.06 grams in the daily feed.

*Feed No. 171. Pepsin and Parcreatin Extract. Started
October 23, 1911.*

The residue left upon the filter in preparing Feed No. 170 was washed thoroughly with hot water and then digested at 40 degrees for one day each with pepsin and pancreatin. The mass was filtered, the filtrate evaporated over a waterbath to a syrup, poured over bran and dried. Each animal was fed daily the amount corresponding to 30 grams of cottonseed meal—double our normal.

Six rabbits were taken, ranging in weight from 1516 to 1864 grams, average 1683. At the end of 38 days the feed was discontinued, the animals having gained an average of 73 grams each.

There were 5.22 grams of P_2O_5 in the total feed or 0.14 grams in the daily feed.

*Feed No. 172. Residue Undissolved by Treatment With Water, Pepsin
and Pancreatin. Started October 23, 1911.*

The mass left after filtering off the solution from which feed No. 171 was prepared was washed with hot water and dried. It was then finely ground in a mill. 8.8 grams corresponding to 15 grams of meal were mixed with bran and molasses and fed to each of six rabbits. The rabbits ranged in weight from 1374 to 1773 grams, average 1592 grams. Five died in 14 to 16 days, and the remaining one died at the end of 27 days—the average of all being 18 days. The average loss in weight was 325 grams. The total feed consumed corresponded to cottonseed meal equivalent to 116 grams per kilo initial average weight of animal, the average for a day being 6.4 grams per kilo. The total P_2O_5 consumed by the average was 1.96 grams, the average for a day being 0.11 grams P_2O_5 .

It is thus seen that the residue undissolved by the treatment of the meal with water, pepsin and pancreatin solution, is toxic but both of the extracts, although they corresponded to almost three or four times as much meal, were non-toxic.

The total P_2O_5 in the toxic portion (1.96 grams) was less than in either of the non-toxic fractions.

*Feed No. 122. Residue Undissolved by Pepsin and Pancreatin.
Started May 4, 1911.*

Cottonseed meal was digested as for feed No. 67 with pepsin and pancreatin. The mass was filtered and the residue was washed with water, dried, and ground. 10.7 grams corresponded to 15 grams of meal. Three rabbits were taken, weighing 1860 and 2284 grams, average 2123 grams. All lost in weight, the average being 552 grams, and all died in an average of 21 days—the range being from 15 to 27 days. The total feed per kilo of animal corresponded to an equivalent of 128 grams of cottonseed meal, the average daily feed being 6.1 grams per kilo. There were in the total average feed 1.40 grams P_2O_5 , making a daily average of 0.07 grams.

This feed resembled closely feed No. 172, both in composition and results and confirms our conclusions that the most toxic part of the meal is in the residue undissolved by pepsin and pancreatin.

We next prepared a feed which had an inappreciable amount of P_2O_5 and yet which was toxic. Our solvent was ammonium citrate solution.

*Feed No. 123. Residue After Citrate Extraction. Started
April 28, 1911.*

450 grams of cottonseed meal were extracted with 1500 c.c. of a solution of ammonium citrate following the A.O.A.C. method for determining insoluble phosphoric acid. The mass was filtered, the residue washed and dried. 7.8 grams were the equivalent of 15 grams of meal.

Four rabbits were placed on the feed April 28, 1911, and one on it on May 21, 1911. The weights ranged from 1350 grams to 2380, average 1602 grams. All lost in weight, the average loss being 438 grams. All died in from 17 to 29 days, the average being 21 days. The total feed-equivalent in cottonseed meal was 168 grams and the daily feed 8.0 grams per kilo of initial live weight.

The total P_2O_5 consumed by each was 0.60 grams, a daily average of 0.03 grams. This feed was almost as toxic as the whole meal or the pepsin pancreatin residue, although it contained but an insignificant amount of P_2O_5 .

Feed No. 182. Sodium Pyrophosphate. Started January 17, 1912.

Twenty-one days of our feed No. 123 (the residue after ammonium citrate extraction), contained a total of 0.60 grams of P_2O_5 . If all the P_2O_5 were in the form of pyrophosphate it would be the equivalent of 1.11 grams of $Na_4P_2O_7$. This amount dissolved in 60 c.c. distilled water was fed on January 17, 1912, at one feeding, through a catheter to each of six rabbits, whose average weight was 1827 grams. The weights

ranged from 1732 to 2037 grams. The average gain for each animal was three grams. The animals did not seem to experience any ill effects from the feed.

As the citrate residue (feed No. 123) which proved toxic in 21 days contained a total of 0.60 grams of P_2O_5 , and as this amount of P_2O_5 in the form of $Na_4P_2O_7$ given at a single feeding to each of six rabbits (feed No. 182) proved harmless, the cause of the toxicity of the citrate residue is not pyrophosphoric acid.

SUMMARY.

Feeds Nos. 67 and 73 show that the pepsin pancreatin extract of cotton seed meal is toxic generally to rabbits, when fed in amounts corresponding to from 15 to 20 times the amount of meal normally fed, and that the pyrophosphoric acid corresponding to this extract is toxic if fed similarly.

Feed No. 120 shows the toxicity of our meal towards our rabbits.

Feeds Nos. 170, 171, and 172 show that the pepsin pancreatin residue is more toxic than the aqueous or pepsin pancreatin extracts of the meal, in fact that it is the only one of the three fractions which is toxic under the conditions of the feeding. Feed No. 122 confirms this conclusion as to the toxicity of the residue.

Feeds Nos. 123 and 182 show that a fraction of cottonseed meal containing a non-toxic amount of pyrophosphoric acid, is toxic.

These feeds considered together indicate that pyrophosphoric acid is not the cause of toxicity of cottonseed meal.

These results are shown in the following table:

Feed	No. of Feed	No. of Animals	Weight of Animals (Grams)		Days Fed	C. S. M. Equivalent Gms. Per Kilo		Grams of P_2O_5 Fed		Fatal?
			Initial	Gain or Loss		Total	Daily	Total	Daily	
P. & P. extr.	67	9	1752	-123	1	114	114.0	2.22	2.22	yes to 5; no to 4 yes
$Na_4P_2O_7$	73	2	1763	-----	1	113	113.0	2.22	2.22	
Raw meal.	120	12	1559	-379	13	100	7.7	2.76	0.21	yes
$Na_4P_2O_7$	124	4	1117	243	52	582	11.2	11.52	0.22	no
Aq. extr.	170	5	1400	203	38	794	23.7	2.26	0.06	no
P. & P. extr.	171	6	1683	73	38	677	17.8	5.22	0.14	no
Res. A., P. & P.	172	6	1592	-325	18	116	6.4	1.96	0.11	yes
Res. P. & P.	122	3	2123	-552	21	128	6.1	1.40	0.07	yes
Citrate res.	123	5	1602	-438	21	168	8.0	0.60	0.03	yes
$Na_4P_2O_7$	182	6	1827	3	1	148	148.0	0.60	0.60	no

FEEDING AND TOXICITY OF COTTONSEED MEAL.

By R. S. CURTIS.

The feeding of cottonseed products to live stock had its beginning about the close of the Civil War, when conditions were such that the farmers who owned live stock were compelled to take advantage of every possible available foodstuff to tide over the emergency. Prior to this time it had not entered the minds of many stockmen that cottonseed products could be used for stock feeding purposes. They occupied the same place as a by-product as did the viscera of slaughtered animals prior to the advent of the modern abattoir. Cottonseed and their products were considered so worthless that they were dumped in the streams nearest to the gin house. The hog more than any other animal is responsible for the discovery that cottonseed was fit for animal food, and that it does contain a constant yet varying toxic property. While the writer is unable to say definitely whether cottonseed products are more fatal to swine than to other domestic animals, suffice it to say that the losses from this source have always been more apparent. Losses by death upon beef cattle, dairy cattle, horses and sheep are reduced almost to nullity compared with the losses from swine, both in practical and experimental feeding. Whether this is due to a greater constitutional immunity on the part of the animals above mentioned, or whether it is due to the peculiar structure of their stomach and alimentary tract (except the horse) the writer is unable to say. However, such is the case and while it is possible to establish a safe and practical method of feeding cottonseed products to beef and dairy cattle, sheep and horses, the writer hesitates to make the statement that the meal will ever enter into general commercial use as a swine feed. Under the watchful eye of an experienced stockman, cottonseed meal can be used with some profit, but for the average farmer it is not considered wise to advocate its general use in the swine ration. This is true for several reasons: First, swine fed on cottonseed meal may thrive for a time, but later an imperceptible reaction takes place which, if not carefully guarded, may bring the animals suddenly into a condition of unthrift. It has been found that as long as good gains are being made there is no special cause for anticipation of danger, but the average farmer does not have scales to make this determination. Second, the premonitory symptoms of cottonseed meal poisoning are not always as striking and as characteristic as one would suspect from the nature of the trouble. Consequently, death may take place during the night following an apparently normal appetite the evening before. While this is not always true in a number of cases it has occurred during the experimental work on the Station farm, involving the use of a few less than one hundred animals.

One of the most striking cases of the absence of premonitory symptoms was seen in a test to determine the difference in the toxicity of Upland and Sea Island cottonseed meal¹ which Crawford of the United States Department of Agriculture had stated was not toxic except under

¹ This investigation was carried on in coöperation with chemical and veterinary divisions of the station.

certain conditions involving the variety of Sea Island seed and the method of manufacturing the meal from this variety. Two hogs were started on a ration of Sea Island cottonseed meal on May 1, 1911. This ration was continued until the early part of November of the same year, when the conclusion was reached that Crawford was right in his statement, and it was therefore decided to discontinue the feeding of the Sea Island seed on November 24 of the same year. As the initial and final weights of all hogs were taken it was directed that these two hogs be weighed on the above date. An attempt was made to drive them from the small lot wherein they had been fed, but it was noticed shortly that the exercise necessitated in driving them from the pen began to have a marked effect on the equilibrium of the body. The hogs were finally driven from the smaller lot into a larger one where the increased exercise had a still greater effect on the stability of the body movements. One hog finally reached the scale chute and just upon entering lost complete control of the body, fell on the side with an intense rigidity of the body, accompanied by a muscular quivering and jerking motion of the body parts. After a few long gasps for breath life became entirely extinct. The original weight of this pig was 105 pounds, final weight 95 pounds, a loss of 10 pounds, although this condition of the animal would not have been suspected on casual examination. Following this most striking death the second pig was driven on the scales and within a few minutes the same condition became apparent as in the former one. The hog was weighed, driven part way down the scale chute when he also lost body control, and within three to four minutes died in the same manner as the former animal had done. The original weight of this pig was 115 pounds, final weight 145 pounds, showing a gain of 30 pounds in the 208 days feeding period, which should have been ample for a 200 pound gain under normal conditions of feed and management.

This discovery¹ has brought out the striking fact that sudden and violent exercise after close penning does have a marked effect on the fatality of the meal, and also the fact that cottonseed meal, if fed to hogs in a large lot where ample exercise can be taken, will not succumb to its effects as readily as otherwise. Whether this will throw any direct light on the problem is to be determined.

To substantiate the discovery that exercise or lack of exercise does have a marked effect on the toxicity of the meal¹ a third hog which was started on Upland cottonseed meal February 1, 1911, was given the same course of treatment as the two former ones. As this hog was about to be taken from the experiment, the exercising was applied with marked results, although death did not occur immediately. On giving this animal severe exercise it apparently became almost totally blind, and lost entire control of the body. The following description of the symptoms were preserved for record.

For several days previous to death the animal was affected with blind staggers, the eyes being slightly closed and a white exudate coming therefrom. The appetite was practically normal until the last. On approaching the animal the characteristic guttural sound of the swine

¹ This investigation was carried on in coöperation with chemical and veterinary divisions of the station.

family was replaced by a sharp rather ferocious noise characteristic of the female which has just farrowed.

After being released from the small pen (where the feeding had been done) into a half acre lot violent exercise occasioned by running the hog about brought on very unsteady movements and finally complete loss of control, the animal falling on its side and remaining in this condition until equilibrium had partly been restored. Upon rising from the recumbent position the movements were still very unsteady and the vision greatly blurred, as shown by frequent contact with fences and other obstacles. After a time, depending on the amount of exercise given, the animal finally regained almost complete control of the body; however, it was still characterized by deep guttural sounds.

This condition continued for several days, the general symptoms gradually growing worse until death finally occurred on the last day of the month, just one year from the time the feeding started.¹

The first attempts to feed cottonseed meal to swine in a practical way were characterized by marked and unsatisfactory results. The writer is of the opinion, however, that much of this trouble was due to an attempt to incorporate more cottonseed meal in the ration than was necessary to properly balance it. In fact, in some instances attempts were made to feed the meal as the major part of the ration, which in itself was an unwise plan. Most all of the Southern Experiment Stations have done some work on this problem and in some instances the northern and western stations have done so in an attempt to find a cheaper source of protein to balance the corn rations almost universally used. Practically all of these stations have abandoned the idea, however, and some of them have as a result bent their energies to the solving of the real problem "the cause of the so-called toxic property." The two southern Experiment stations most ardent in recommending the practical use of cottonseed meal in the swine ration are Arkansas and Alabama.

Dinwiddie of the Arkansas Station, in Bulletin 85, recommends feeding it as follows:

Pigs under 50 lbs.	$\frac{1}{4}$ lb. per day.
50-75 lbs.	$\frac{1}{8}$ lb. per day.
75-100 lbs.	$\frac{1}{4}$ lb. per day.
100-150 lbs.	$\frac{1}{2}$ lb. per day.

While these figures are apparently made on a conservative basis, even these dosages have been known to kill at this and other Experiment Stations, which makes this guide or system recommended not always free from causing deleterious effects. Illustrating this statement, the writer will give a few examples from work carried on at the North Carolina Station.

On November 4, 1908, 16 pigs were started on cottonseed meal rations,¹ the total daily ration aggregating one pound of concentrates for each animal. Of this amount the proportion of cottonseed meal fed ranged from one-fifth of a pound to one-half pound per day. One pig fed cottonseed meal and corn meal in the proportion of 1 to 5 died in

¹ This investigation was carried on in coöperation with chemical and veterinary divisions of the station.

30 days; another on the same ration in 53 days; and still another on the same ration in 63 days. One pig fed cottonseed meal and corn meal in the proportion of 1 to 3 died in 49 days; two more fed on cottonseed meal and corn meal in the proportion of 1 to 2, died in 78 and 88 days respectively. Notice here the contradiction of the Arkansas report where the least amount killed in the shortest time in fact, if the guide given by that station had been reversed it would have applied much better in this case. Still another hog fed cottonseed meal and corn meal in the proportion of 1 to 1 died in 49 days. With this one exception the pigs fed the largest amount of cottonseed meal lived throughout the experiment, and were discontinued on the 91st day in good condition, apparently, at least from all outward indications.

Other experiments at this Station show records of four hogs which have been fed over 300 days on pure cottonseed meal, and with one exception without causing death, and in this case it occurred on the 326th day. One of these four hogs was discontinued on the 414th day, having consumed 637.5 pounds of cottonseed meal, enough to kill six or more hogs under other conditions such as might be caused by a different brand of meal, the individuality of the hogs or their management. This amount of meal would have fattened a 700 pound steer in good condition for market and furnished a more desirable product than the average animal butchered. A number of cases are on record here where hogs have been fed 200 days and over without causing death.

Various treatments have failed to eliminate all or any appreciable part of the toxic property of the meal from a commercial standpoint. Steaming, roasting, boiling, souring, and fermenting have all been tried, but without definite results from a practical viewpoint.

Dinwiddie, of Arkansas, makes the following statement: "The harmful effects of overfeeding with cottonseed meal are manifested in all species of animals so far tested. Hogs exhibit no great excess of susceptibility over cattle when fed in doses proportionate to their weight." In view of later evidence the writer questions this statement somewhat at least from a practical viewpoint, since we have been unable to substitute cottonseed meal even as a supplement to swine rations with any marked and regular success, while with beef cattle we are able to use cottonseed meal as the sole concentrate and in quantities sufficient to put cattle in a highly finished condition for the buyer of fancy grades of cattle.

NORTH CAROLINA
Agricultural Experiment Station
West Raleigh

C. B. WILLIAMS, *Director.*

PRESS BULLETIN No. 24

SEPTEMBER 27, 1911.

**A Serious Cotton Disease (Anthracnose) and
How to Handle It**

There is a disease of cotton which is yearly attracting increased attention throughout the cotton belt. It is known as cotton anthracnose.

It is most easily recognized when on the boll, where it forms ulcer-like spots, which, as they age, become pink in the centers. The spot may enlarge so as to affect the whole boll. The diseased part of the boll usually fails to open and often the contents rot. Enquiries from various sections of the State are being received almost daily at the Experiment Station concerning the disease. It has also been especially severe in Alabama and Georgia during recent years, so severe in the latter State that the Legislature has made a large special appropriation for its investigation.

Although the disease is seen and recognized most prominently on the bolls, it also occurs on the leaves and stems. Cotton growers should know that this disease is carried from season to season on the seed, and that seed from a sick boll, even though very slightly diseased, may raise a diseased plant, and this in turn may spread the disease to the whole crop of the next season. There is no satisfactory treatment, and the one point to be remembered is that seed from diseased fields is likely to carry the disease, in fact, almost sure to do so. Even seed from clean fields which has passed through a gin in which diseased cotton has been ginned is dangerous. It is of utmost importance for the grower to be sure that his cotton seed does not come from a field or from a region where this disease prevails.

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